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The Psychological Foundations of Culture

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INTRODUCTION: THE UNITY OF SCIENCE[1]

> One of the strengths of scientific inquiry is that it can progress with any mixture of empiricism, intuition, and formal theory that suits the convenience of the investigator. Many sciences develop for a time as exercises in description and empirical generalization. Only later do they acquire reasoned connections within themselves and with other branches of knowledge. Many things were scientifically known of human anatomy and the motions of the planets before they were scientifically explained.
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> —GEORGE WILLIAMS,
> *Adaptation and Natural Selection*

Disciplines such as astronomy, chemistry, physics, geology, and biology have developed a robust combination of logical coherence, causal description, explanatory power, and testability, and have become examples of how reliable and deeply satisfying human knowledge can become. Their extraordinary florescence throughout this century has resulted in far more than just individual progress within each field. These disciplines are becoming integrated into an increasingly seamless system of interconnected knowledge and remain nominally separated more out of educational convenience and institutional inertia than because of any genuine ruptures in the underlying unity of the achieved knowledge. In fact, this development is only an acceleration of the process of conceptual unification that has been building in science since the Renaissance. For example, Galileo and Newton broke down the then rigid (and now forgotten) division between the celestial and the terrestrial—two domains that formerly had been considered metaphysically separate—showing that the same processes and principles applied to both. Lyell broke down the distinction between the static present and the formative past, between the creative processes operating in the present and the geological processes that had operated across deep time to sculpt the earth. Maxwell uncovered the elegant principles that unified the many disparate electrical and magnetic phenomena into a single system.

And, one by one, the many gulfs separating life from nonlife were bridged and then closed: Harvey and others found that the macrostructure of the body turned out to operate according to comprehensible mechanical principles. Wöhler's synthesis of urea showed that the chemistries of the living and the nonliving were not forever separated by the occult operation of special vitalistic forces. In Wöhler's wake, the unraveling of the molecular biology of the gene and its regulation of cellular processes has shown how many of the immensely complex and functionally intricate mechanisms that constitute life are realized in molecular machinery: the *élan vital* turned out to be nothing other than this microscopic functional intricacy. Most critically, Darwin showed how even the intricately articulated functional organization of living systems (then only observable at the macroscopic level) could be explained as the product of intelligible natural causes operating over the expanse of deep time. In so doing, he conceptually united the living and the nonliving into a single system of principled causation, and the entire diversity of plant, animal, and microbial species into a single tree of descent. Darwin took an equally radical step toward uniting the mental and physical worlds, by showing how the mental world—whatever it might be composed of—arguably owed its complex organization to the same process of natural selection that explained the physical organization of living things. Psychology became united with the biological and hence evolutionary sciences.

The rise of computers and, in their wake, modern cognitive science, completed the conceptual unification of the mental and physical worlds by showing how physical systems can embody information and meaning. The design and construction of artificial computational systems is only a few decades old, but already such systems can parallel in a modest way cognitive processes—such as reason, memory, knowledge, skill, judgment, choice, purpose, problem-solving, foresight, and language—that had supposedly made mind a metaphysical realm forever separated from the physical realm, and humans metaphysically disconnected from the causal network that linked together the rest of the universe. These intellectual advances transported the living, the mental, and the human—three domains that had previously been disconnected from the body of science and mystified because of this disconnection—into the scientifically analyzable landscape of causation.

One useful way to organize this knowledge is as a principled history of the universe. Starting with some characterizable initial condition (like the Big Bang), each successive state of the system is described, along with the principles that govern the transitions from state to state. To the extent that our scientific model is well-developed, we should be able to account for the types of entities that emerge (pulsars, tectonic plates, ribosomes, vision, incest avoidance) and their distribution and location in the causal matrix. Such a history—in its broadest outlines—is well on its way to being constructed, from an initial quantum state, to the formation and distribution of particles during the early expansion, to the cooling and formation of atoms, the formation of galaxies, stellar evolution, the synthesis of heavier nuclei, and, of parochial interest to us, the local history of the solar system. This includes the formation of the sun and planets; the geochemistry of prebiotic earth; the generation of complex organic compounds; the emergence of the initial ancestral reproducing chemical system; the evolution of the genetic code and prokaryotic design; the emergence of eukaryotic sexual organisms, multicellular plants, animals, and fungi; and the rest of the history of life on earth.

In this vast landscape of causation, it is now possible to locate "Man's place in nature" to use Huxley's famous phrase and, therefore, to understand for the first time what humankind is and why we have the characteristics that we do. From this vantage point, humans are self-reproducing chemical systems, multicellular heterotrophic mobile organisms (animals), appearing very late in the history of life as somewhat modified versions of earlier primate designs. Our developmental programs, as well as the physiological and psychological mechanisms that they reliably construct, are the natural product of this evolutionary history. Human minds, human behavior, human artifacts, and human culture are all biological phenomena—aspects of the phenotypes of humans and their relationships with one another.

The rich complexity of each individual is produced by a cognitive architecture, embodied in a physiological system, which interacts with the social and nonsocial world that surrounds it. Thus humans, like every other natural system, are embedded in the contingencies of a larger principled history, and explaining any particular fact about them requires the joint analysis of all the principles and contingencies involved. To break this seamless matrix of causation—to attempt to dismember the individual into "biological" versus "nonbiological" aspects—is to embrace and perpetuate an ancient dualism endemic to the Western cultural tradition: material/spiritual, body/mind, physical/mental, natural/human, animal/human, biological/social, biological/cultural. This dualistic view expresses only a premodern version of biology, whose intellectual warrant has vanished.

This expansive new landscape of knowledge has not always been welcome, and many have found it uncongenial in one respect or another. The intellectual worlds we built and grew attached to over the last 3,000 years were laid out before much was known about the nature of the living, the mental, and the human. As a result, these intellectual worlds are, in many important respects, inconsistent with this new unified scientific view and, hence, are in need of fundamental reformulation. These established intellectual traditions and long-standing habits of mind seem, to many, to be more nourishing, more comfortable and, therefore, more valuable than the alternative prospect of new and unfamiliar scientific knowledge. To pick a single example, the shift from a universe designed to embody a moral and spiritual order to a universe that is undesigned and is structured only by a causal order engendered an immeasurably greater cultural dislocation than that which occurred when Copernicus identified the sun rather than the earth as the center of the planetary orbits. Consequently, the demystifications that have taken place since 1859 have been painful and have precipitated considerable resistance to accepting these discoveries and their implications. With the appearance of Darwinism, the full scope of the emerging unified account was, for the first time, apparent. Therefore, much of the opposition has specifically revolved around evolution and its application to humans. Gladstone, for example, in a debate with Huxley, captured in his choice of language the widely shared, visceral sense of revulsion caused by the claim "that natural selection and the survival of the fittest, all in the physical order, exhibit to us the great arcanum of creation, the sun and the center of life, so that mind and spirit are dethroned from their old supremacy, are no longer sovereign by right, but may find somewhere by charity a place assigned them, as appendages, perhaps only as excrescences, of the material creation" (Gladstone, quoted in Gould, 1988, p. 14). The dislocations in world view stemming from this process of conceptual unification led to a growing demand for, and production of, conceptual devices and rationales to divorce the natural sciences from the human social and inner landscape, to blunt the implications of monism and Darwinism, and to restore a comfortable distance between the human sciences and the world of natural causation. To many scholarly communities, conceptual unification became an enemy, and the relevance of other fields a menace to their freedom to interpret human reality in any way they chose.

Thus, despite some important exceptions, the social sciences have largely kept themselves isolated from this crystalizing process of scientific integration. Although social scientists imitated many of the outward forms and practices of natural scientists (quantitative measurement, controlled observation, mathematical models, experimentation, etc.), they have tended to neglect or even reject the central principle that valid scientific knowledge—whether from the same or different fields—should be mutually consistent (see Cosmides, Tooby, & Barkow, this volume). It is this principle that makes different fields relevant to each other, and part of the same larger system of knowledge. In consequence, this insularity is not just an accident. For many scholars, it has been a conscious, deeply held, and strongly articulated position, advanced and defended since the inception of the social sciences, particularly in anthropology and sociology. Durkheim, for example, in his *Rules of the Sociological Method*, argued at length that social phenomena formed an autonomous system and could be only explained by other social phenomena (1895/1962). The founders of American anthropology, from Kroeber and Boas to Murdock and Lowie, were equally united on this point. For Lowie, "the principles of psychology are as incapable of accounting for the phenomena of culture as is gravitation to account for architectural styles," and "culture is a thing *sui generis* which can be explained only in terms of itself. . . . *Omnis cultura ex cultura*" (1917/1966, p. 25–26; p. 66). Murdock, in his influential essay "The science of culture," summed up the conventional view that culture is "independent of the laws of biology and psychology" (1932, p. 200).

Remarkably, while the rest of the sciences have been weaving themselves together through accelerating discoveries of their mutual relevance, this doctrine of intellectual isolationism, which has been the reigning view in the social sciences, has only become more extreme with time. With passionate fidelity, reasoned connections with other branches of knowledge are dismissed as ignorant attempts at crude reductionism, and many leading social scientists now openly call for abandoning the scientific enterprise instead. For example, Clifford Geertz advocates abandoning the ground of principled causal analysis entirely in favor of treating social phenomena as "texts" to be interpreted just as one might interpret literature: We should "turn from trying to explain social phenomena by weaving them into grand textures of cause and effect to trying to explain them by placing them into local frames of awareness" (1983, p. 6). Similarly, Edmund Leach rejects scientific explanation as the focus of anthropology: "Social anthropology is not, and should not aim to be, a 'science' in the natural science sense. If anything it is a form of art . . . . Social anthropologists should not see themselves as seekers after objective truth . . . ." (Leach, 1982, p. 52). These positions have a growing following, but less, one suspects, because they have provided new illumination than because they offer new tools to extricate scholars from the unwelcome encroachments of more scientific approaches. They also free scholars from all of the arduous tasks inherent in the attempt to produce scientifically valid knowledge: to make it consistent with other knowledge and to subject it to critical rejection on the basis of empirical disproof, logical inconsistency, and incoherence. In any case, even advocates of such avenues of retreat do not appear to be fully serious about them because few are actually willing to accept what is necessarily entailed by such a stance: Those who jettison the epistemological standards of science are no longer in a position to use their intellectual product to make any claims about what is true of the world or to dispute the others' claims about what is true.

Not only have the social sciences been unusual in their self-conscious stance of intellectual autarky but, significantly, they have also been relatively unsuccessful as sciences. Although they were founded in the 18th and 19th centuries amid every expectation that they would soon produce intellectual discoveries, grand "laws," and validated theories to rival those of the rest of science, such success has remained elusive. The recent wave of antiscientific sentiment spreading through the social sciences draws much of its appeal from this endemic failure. This disconnection from the rest of science has left a hole in the fabric of our organized knowledge of the world where the human sciences should be. After more than a century, the social sciences are still adrift, with an enormous mass of half-digested observations, a not inconsiderable body of empirical generalizations, and a contradictory stew of ungrounded, middle-level theories expressed in a babel of incommensurate technical lexicons. This is accompanied by a growing malaise, so that the single largest trend is toward rejecting the scientific enterprise as it applies to humans.

We suggest that this lack of progress, this "failure to thrive," has been caused by the failure of the social sciences to explore or accept their logical connections to the rest of the body of science—that is, to causally locate their objects of study inside the larger network of scientific knowledge. Instead of the scientific enterprise, what should be jettisoned is what we will call the Standard Social Science Model (SSSM): The consensus view of the nature of social and cultural phenomena that has served for a century as the intellectual framework for the organization of psychology and the social sciences and the intellectual justification for their claims of autonomy from the rest of science. Progress has been severely limited because the Standard Social Science Model mischaracterizes important avenues of causation, induces researchers to study complexly chaotic and unordered phenomena, and misdirects study away from areas where rich principled phenomena are to be found. In place of the Standard Social Science Model, there is emerging a new framework that we will call the Integrated Causal Model. This alternative framework makes progress possible by accepting and exploiting the natural connections that exist among all the branches of science, using them to construct careful analyses of the causal interplay among all the factors that bear on a phenomenon. In this alternative framework, nothing is autonomous and all the components of the model must mesh.

In this chapter, we argue the following points:

1. There is a set of assumptions and inferences about humans, their minds, and their collective interaction—the Standard Social Science Model—that has provided the conceptual foundations of the social sciences for nearly a century and has served as the intellectual warrant for the isolationism of the social sciences.
2. Although certain assumptions of this model are true, it suffers from a series of major defects that make it a profoundly misleading framework. These defects have been responsible for the chronic difficulties encountered by the social sciences.
3. Advances in recent decades in a number of different disciplines, including evolutionary biology, cognitive science, behavioral ecology, psychology, hunter-gatherer studies, social anthropology, biological anthropology, primatology, and neurobiology have made clear for the first time the nature of the phenomena studied by social scientists and the connections of those phenomena to the principles and findings in the rest of science. This allows a new model to be

constructed—the Integrated Causal Model—to replace the Standard Social Science Model.

4. Briefly, the ICM connects the social sciences to the rest of science by recognizing that:

   a. the human mind consists of a set of evolved information-processing mechanisms instantiated in the human nervous system;
   b. these mechanisms, and the developmental programs that produce them, are adaptations, produced by natural selection over evolutionary time in ancestral environments;
   c. many of these mechanisms are functionally specialized to produce behavior that solves particular adaptive problems, such as mate selection, language acquisition, family relations, and cooperation;
   d. to be functionally specialized, many of these mechanisms must be richly structured in a content-specific way;
   e. content-specific information-processing mechanisms generate some of the particular content of human culture, including certain behaviors, artifacts, and linguistically transmitted representations;
   f. the cultural content generated by these and other mechanisms is then present to be adopted or modified by psychological mechanisms situated in other members of the population;
   g. this sets up epidemiological and historical population-level processes; and
   h. these processes are located in particular ecological, economic, demographic, and intergroup social contexts or environments.

On this view, culture is the manufactured product of evolved psychological mechanisms situated in individuals living in groups. Culture and human social behavior is complexly variable, but not because the human mind is a social product, a blank slate, or an externally programmed general-purpose computer, lacking a richly defined evolved structure. Instead, human culture and social behavior is richly variable because it is generated by an incredibly intricate, contingent set of functional programs that use and process information from the world, including information that is provided both intentionally and unintentionally by other human beings.

THE STANDARD SOCIAL SCIENCE MODEL

The Central Logic of the Standard Social Science Model

> But one would be strangely mistaken about our thought if, from the foregoing, he drew the conclusion that sociology, according to us, must, or even can, make an abstraction of man and his faculties. It is clear, on the contrary, that the general characteristics of human nature participate in the work of elaboration from which social life results. But they are not the cause of it, nor do they give it its special form; they only make it possible. Collective representations, emotions, and tendencies are caused not by certain states of the consciousnesses of individuals but by the conditions in which the social group, in its totality, is placed. Such actions can, of course materialize only if the individual natures are not resistant to them; *but these individual natures are merely the indeterminate material that the social factor molds and transforms. Their contribution consists exclusively in very general attitudes, in vague and consequently plastic predispositions* which, by themselves, if other agents did not intervene, could not take on the definite and complex forms which characterize social phenomena.
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> —DURKHEIM, 1895/1962, pp. 105–106, emphasis added.

Humans everywhere show striking patterns of local within-group similarity in their behavior and thought, accompanied by profound intergroup differences. The Standard Social Science Model (SSSM or Standard Model) draws its enduring persuasive power by starting with these and a few other facts, rooted in direct experience and common knowledge. It then focuses on one salient causal and temporal sequence: how individuals change over their development from "unformed" infants into complexly competent adult members of their local social group, and how they do so in response to their local human environment. The central precepts of the SSSM are direct and seemingly inescapable conclusions drawn from these facts (D. E. Brown, 1991), and the same reasoning appears in author after author, from perhaps its most famous early expression in Durkheim (1895/1962), to its fully conventional modern adherents (with updated conceptual ornamentation) such as Geertz (1973).

The considerations that motivate the Standard Social Science Model are as follows:

Step 1. The existence of rapid historical change and the multitude of spontaneous human "cross-fostering experiments" effectively disposes of the racialist notion that human intergroup behavioral differences of any significance are attributable to genetic differences between groups. Infants everywhere are born the same and have the same developmental potential, evolved psychology, or biological endowment—a principle traditionally known as *the psychic unity of humankind.* The subsequent growth of knowledge over this century in genetics and human development has given strong empirical support to the conclusion that infants from all groups have essentially the same basic human design and potential. Human genetic variation, which is now directly detectable with modern electrophoretic techniques, is overwhelmingly sequestered into functionally superficial biochemical differences, leaving our complex functional design universal and species-typical (Tooby & Cosmides, 1990a). Also, the bulk of the variation that does exist is overwhelmingly inter-individual and within-population, and not between "races" or populations. By the nature of its known distribution, then, genetic variation cannot explain why many behaviors are shared within groups, but not between groups. That is, genetic variation does not explain why human groups dramatically differ from each other in thought and behavior. (Significantly, this is the only feature of the SSSM that is correct as it stands and that is incorporated unmodified into the Integrated Causal Model. Why it turns out to be true, however, depends on the existence of complex evolved psychological and physiological adaptations—something explicitly or implicitly denied by adherents of the SSSM.)

Step 2. Although infants are everywhere the same, adults everywhere differ profoundly in their behavioral and mental organization.

These first two steps, just by themselves, have led to the following widely accepted deduction: Because, it is reasoned, a "constant" (the human biological endowment observable in infants) cannot explain a "variable" (intergroup differences in complex adult mental or social organization) the SSSM concludes that "human nature" (the evolved structure of the human mind) cannot be the cause of the mental organization of adult humans, their social systems, their culture, historical change, and so on.

Step 3. Even more transparently, these complexly organized adult behaviors are absent from infants. Infants do not emerge speaking, and they appear to lack virtually every recognizable adult competency. Whatever "innate" equipment infants are born with has traditionally been interpreted as being highly rudimentary, such as an unorganized set of crude urges or drives, plus the ability to learn—certainly nothing resembling adult mental organization. Because adult mental organization (patterned behavior, knowledge, socially constructed realities, and so on) is clearly absent from the infant, infants must "acquire" it from some source outside themselves in the course of development.

Step 4. That source is obvious: This mental organization is manifestly present in the social world in the form of the behavior and the public representations of other members of the local group. Thus, the stuff of mental organization is categorizable according to its source: (1) the "innate" (or inborn or genetically determined, etc.), which is supplied "biologically" and is what you see in the infant, and (2) the social (or cultural or learned or acquired or environmental), which contains everything complexly organized and which is supplied by the social environment (with a few exceptions supplied by the physical environment and nonsocial learning). "[C]ultural phenomena ... are in no respect hereditary but are characteristically and without exception acquired" (Murdock, 1932, p. 200). This line of reasoning is usually supported by another traditional argument, the deprivation thought experiment: "Undirected by culture patterns—organized systems of significant symbols—man's behavior would be virtually ungovernable, a mere chaos of pointless acts and exploding emotions, his experience virtually shapeless" (Geertz, 1973, p. 46). Humans raised without a social or cultural environment would be "mental basket cases" with "few useful instincts, fewer recognizable sentiments, and no intellect" (Geertz, 1973, p. 49). Because, it is reasoned, an effect disappears when its cause is withdrawn, this thought experiment is believed to establish that the social world is the cause of the mental organization of adults.

Step 5. The causal arrow in this process has a clear directionality, which is directly observable in the individual's development. The cultural and social elements that mold the individual precede the individual and are external to the individual. The mind did not create them; they created the mind. They are "given," and the individual "finds them already current in the community when he is born" (Geertz, 1973, p. 45). Thus, the individual is the creation of the social world and, it appears to follow, the social world cannot be the creation of "the individual." If you are reading this chapter, you learned English and did not create it. Nor did you choose to learn English (assuming you are a native speaker) any more than any effect chooses its cause; this action of the social world on the individual is compulsory and automatic—"coercive," to use Durkheim's phrase. Adult mental organization is socially determined. Moreover, by looking at social processes in the vast modern societies and nation-states, it is obvious that the "power asymmetry" between "the individual" and the social world is huge in the determination of outcomes and that the reciprocal impact of the individual on the social world is negligible. The causal flow is overwhelmingly or entirely in one direction. The individual is the acted upon (the effect or the outcome) and the sociocultural world is the actor (the cause or the prior state that determines the subsequent state).

Step 6. Accordingly, what complexly organizes and richly shapes the substance of human life—what is interesting and distinctive and, therefore, worth studying—is the variable pool of stuff that is usually referred to as "culture." Sometimes called "extrasomatic" or "extragenetic" (e.g., Geertz, 1973) to emphasize its nonbiological origins and nature, this stuff is variously described as behavior, traditions, knowledge, significant symbols, social facts, control programs, semiotic systems, information, social organization, social relations, economic relations, intentional worlds, or socially constructed realities. However different these characterizations may appear to be in some respects, those who espouse them are united in affirming that this substance—whatever its character—is (in Durkheim's phrase) "external to the individual." Even so psychological a phenomenon as thinking becomes external: "Human thought is basically both social and public—. . . its natural habitat is the house yard, the marketplace, and the town square. Thinking consists not of 'happenings in the head' (though happenings there and elsewhere are necessary for it to occur) but of a traffic in what have been called, by G.H. Mead and others, significant symbols—words for the most part. . . ." (Geertz, 1973, p. 45). "The individual" contributes only the infant's impoverished drives, unformed tendencies, and capacity to be socialized.

These first six steps constitute the SSSM's account of the causal process whereby what is assumed to be an initially formless infant is transformed into a fully human (i.e., fully cultural) being. The next important element in the SSSM is its approach to answering the question, "If culture creates the individual, what then creates culture?"

Before describing the SSSM's answer to this question, however, we need to make an important aspect of the question explicit: Human life is complexly and richly ordered. Human life is not (solely) noise, chaos, or random effect (contra Macbeth). Although the substance of human life, like human speech, is various and contingent, it is still, like human speech, intricately patterned. Many attempt to capture this perception with the phrase that human cultures (e.g., human symbol systems) are "meaningful." Human conduct does not resemble white noise. In a way that is analogous to William Paley's argument from design in his *Natural Theology*, one must ask: If there is complex and meaningful organization in human sociocultural life, what is the creator or artificer of it? Entropy, perturbation, error, noise, interaction with other systems, and so on, are always operating to influence culture (and everything else), so clearly not everything in culture is orderly. Equally, if these processes were all that were operating, complex order would never appear and would quickly degrade even if it did. Just as finding a watch on the heath, already complexly organized, requires that one posit a watchmaker (Paley, 1828), finding out that human life is complexly ordered necessitates the search for the artificer or source of this order (see Dawkins, 1986, for an exceptionally lucid general analysis of the problem of explaining complex order, its importance as a question, and the extremely narrow envelope of coherent answers). So, the question is not so much, What are the forces that act on and influence human culture and human affairs? but rather, What is the generator of complex and significant *organization* in human affairs?

Step 7. The advocates of the Standard Social Science Model are united on what the artificer is not and where it is not: It is not in "the individual"—in human nature or evolved psychology—which, they assume, consists of nothing more than what the infant comes equipped with, bawling and mewling, in its apparently unimpressive initial performances. Because the directional flow of the organization is from the outer world inward into "the individual," the direction toward which one looks for the source of the organization is likewise clear: outward into the social world. As Durkheim says, "[w]hen the individual has been eliminated, society alone remains" (1895/1962, p. 102).

Step 8. The SSSM maintains that the generator of complex and meaningful organization in human life is some set of emergent processes whose determinants are realized at the group level. The sociocultural level is a distinct, autonomous, and self-caused realm: "Culture is a thing *sui generis* which can be explained only in terms of itself. . . . *Omnis cultura ex cultura*" (Lowie, 1917/1966, p. 25–26). For Alfred Kroeber, "the only antecedents of historical phenomena are historical phenomena" (Kroeber, 1917). Durkheim was equally emphatic: "The determining cause of a social fact should be sought among the social facts preceding it and not among the states of individual consciousness"; that is, phenomena at the sociocultural level are mostly or entirely caused by other phenomena at the sociocultural level (Durkheim, 1895/1962, p. 110). It must be emphasized that this claim is not merely the obvious point that social phenomena (such as tulip bulb mania, the contagious trajectory of deconstructionist fashions, or the principles of supply and demand) cannot be understood simply by pointing inside the head of a single individual. It is, instead, a claim about the *generator* of the rich organization everywhere apparent in human life. What is generated even includes individual adult psychological phenomena, which are themselves simply additional social constructions. For Durkheim (and for most anthropologists today), even emotions such as "sexual jealousy" and "paternal love" are the products of the social order and have to be explained "by the conditions in which the social group, in its totality, is placed." As Geertz argues, "Our ideas, our values, our acts, even our emotions, are, like our nervous system itself, cultural products—products manufactured, indeed, out of tendencies, capacities, and dispositions with which we were born, but manufactured nonetheless" (1973, p. 50). Similarly, Shweder describes "cultural psychology" as "the study of the way cultural traditions and social practices regulate, express, transform, and permute the human psyche, resulting less in psychic unity for humankind than in ethnic divergences in mind, self and emotion" (Shweder, 1990, p. 1).

Step 9. Correspondingly, the SSSM denies that "human nature"—the evolved architecture of the human mind—can play any notable role as a generator of significant organization in human life (although it is acknowledged to be a necessary condition for it). In so doing, it removes from the concept of human nature all substantive content, and relegates the architecture of the human mind to the delimited role of embodying "the capacity for culture." Human nature is "merely the indeterminate material that the social factor molds and transforms. [This] contribution consists exclusively in very general attitudes, in vague and consequently plastic predispositions which, by themselves, if other agents did not intervene, could not take on the definite and complex forms which characterize social phenomena" (Durkheim, 1895/1962, p. 106). As Hatch comments, the "view that the Boasians had struggled to foster within the social sciences since almost the turn of the century" was that the human mind is "almost infinitely malleable" (1973, p. 236). Socialization is the process of externally supplied "conceptual structures molding formless talents" (Geertz, 1973, p. 50).

Social scientists who paid any attention to neuroscience, ethology, and cognitive psychology were increasingly, if uneasily, aware of the evidence that the nervous system was complex and not well characterized by the image of the "blank slate." Nonetheless, aside from paying some lip service to the notion that *tabula rasa* empiricism was untenable, this changed nothing important in the SSSM. The blank slate was traded in for blank cognitive procedures.[2] The mind could be seen as complex, but its procedures were still assumed to be content-free. As long as environmental input could enter and modify the system, as it clearly could, environmental input was presumed to orchestrate the system, giving it its functional organization. It doesn't matter if the clay of the human mind has some initial shape (tendencies, dispositions), so long as it is soft enough to be pounded by the external forces into any new shape required. Thus, for Geertz, who is attracted to the language if not the actual substance of cognitive science, the mind is not a slate, blank or otherwise (he dismisses this as a straw man position "which no one of any seriousness holds" or perhaps ever held [Geertz, 1984, p. 268]), but it is instead the tabula rasa's fully modern equivalent, a general-purpose computer. Such a computer doesn't come pre-equipped with its own programs, but instead—and this is the essential point—it obtains the programs that tell it what to do from the outside, from "culture." Thus, the human mind is a computer that is "desperately dependent upon such extragenetic, outside-the-skin control mechanisms" or "programs" "for the governing of behavior" (Geertz, 1973, p. 44).

This eliminates the concept of human nature or its alternative expression, the evolved psychological architecture, as useful or informative concepts. As Geertz puts it, "[t]he rise of the scientific concept of culture amounted to . . . the overthrow of the view of human nature dominant in the Enlightenment . . .", that is, that "[man] was wholly of a piece with nature and shared in the general uniformity of composition which natural science . . . had discovered there" with "a human nature as regularly organized, as thoroughly invariant, and as marvelously simple as Newton's universe" (Geertz, 1973, p. 34). Instead, the view entailed in the modern "scientific concept of culture" is that "humanity is as various in its essence as in its expression" (Geertz, 1973, p. 37). Geertz does not mean, of course, that infants vary due to genetic differences, but that all significant aspects of adult mental organization are supplied culturally. As deeply as one can go into the mind, people here are different from people there, leading to "the decline of the uniformitarian view of man" (Geertz, 1973, p. 35).

The conclusion that human nature is an empty vessel, waiting to be filled by social processes, removed it as a legitimate and worthwhile object of study. Why study paper when what is interesting is the writing on it and, perhaps even more important, the author (the perennially elusive generative social processes)? Since there could be no content, per se, to the concept of human nature, anything claimed to be present in human nature was merely an ethnocentric projection of the scholar making the claim. Thus, attempts to explore and characterize human nature became suspect. Such efforts were (and are) viewed as simply crude attempts to serve ideological ends, to manufacture propaganda, or to define one way of being as better and more natural than others.

Step 10. In the SSSM, the role of psychology is clear. Psychology is the discipline that studies the process of socialization and the set of mechanisms that comprise what anthropologists call "the capacity for culture" (Spuhler, 1959). Thus, the central concept in psychology is learning. The prerequisite that a psychological theory must meet to participate in the SSSM is that any evolved component, process, or mechanism must be equipotential, content-free, content-independent, general-purpose, domain-general, and so on (the technical terms vary with movement and era). In short, these mechanisms must be constructed in such a way that they can absorb any kind of cultural message or environmental input equally well. Moreover, their structures must themselves impose no particular substantive content on culture. As Rindos (1986, p.

315) puts it, "the specifics that we learn are in no sense predetermined by our genes." Learning is thus the window through which the culturally manufactured pre-existing complex organization outside of the individual manages to climb inside the individual. Although this approach deprives psychological mechanisms of any possibility of being the generators of significant organization in human affairs, psychologists get something very appealing in exchange. Psychology is the social science that can hope for general laws to rival those of the natural sciences: general laws of learning, or (more recently) of cognitive functioning. The relationship of psychology to biology is also laid out in advance by the SSSM: In human evolution, natural selection removed "genetically determined" systems of behavior and replaced them with general-purpose learning mechanisms or content-independent cognitive processes. Supposedly, these more general systems were favored by evolution because they did not constrain human behavior to be maladaptively inflexible (e.g., Geertz, 1973; Harris, 1979; Montagu, 1964). Neurobiology is the account of how these general mechanisms are instantiated in our nervous system.

Consequently, the concepts of learning, socialization, general-purpose (or content-independent) cognitive mechanisms, and environmentalism have (under various names and permutations) dominated scientific psychology for at least the last 60 years. Skinnerian behaviorism, of course, was one of the most institutionally successful manifestations of the SSSM's program for psychology, but its antimentalism and doctrinaire scientism made it uncongenial to those who wanted an account of their internal experience. More importantly, its emphasis on individual histories of reinforcement limited the avenues through which culture could have its effect. It proved an easy target when cognitive science provided precise ways of characterizing and investigating the mental as a system that processes information, a characterization that seemed to offer easier avenues for cultural transmission than laboriously organized schedules of reinforcement. Although cognitive psychologists threw out behaviorism's cumbersome antimentalism, they uncritically adopted behaviorism's equipotentiality assumption. In mainstream cognitive psychology, it is *assumed* that the machine is free of content-specialized processes and that it consists primarily of general-purpose mechanisms. Psychologists justify this assumption by an appeal to parsimony: It is "unscientific" to multiply hypothesized mechanisms in the head. The goal, as in physics, is for as few principles as possible to account for as much as possible. Consequently, viewing the mind as a collection of specialized mechanisms that perform specific tasks appears to be a messy approach, one not worth pursuing. Anthropologists and sociologists easily accommodated themselves to these theoretical changes in psychology: Humans went from being viewed as relatively simple equipotential learning systems to very much more complex equipotential information-processing systems, general-purpose computers, or symbol manipulators (see, e.g., Sahlins, 1976a, 1976b).

Within psychology there are, of course, important research communities that fall outside of the SSSM and that have remained more strongly connected to the rest of science, such as physiological psychology, perception, psychophysics, (physiological) motivation, psycholinguistics, much of comparative psychology, and a few other areas. Moreover, to explain how organisms remain alive and reproduce (and to make some minimal attempt to account for the focused substance of human life), psychologists have found it necessary to posit a few content-oriented mechanisms: hunger, thirst, sexual motivation, and so on. Nevertheless, the tendency has been to keep these elements restricted to as small a class as possible and to view them as external to the important central learning or cognitive processes. They are incorporated as, for example, reinforcers operating by drive reduction. Cognitive psychologists have, for the most part, labored to keep any such content-influenced elements extrinsic to the primary cognitive machinery. Indeed, they have usually avoided addressing how functional action—such as mate choice, food choice, or effort calculation—takes place at all. The principles of concept formation, of reasoning, of remembering, and so forth, have traditionally been viewed as uninfected prior to experience with any content, their procedures lacking features designed for dealing with particular types of content. Modular or domain-specific cognitive psychologists, in dissenting from this view, are abandoning the assumptions of the Standard Social Science Model.

Of course, readers should recognize that by so briefly sketching large expanses of intellectual history and by so minimally characterizing entire research communities, we are doing violence to the specific reality of, and genuine differences among hundreds of carefully developed intellectual systems. We have had to leave out the qualifications and complexities by which positions are softened, pluralisms espoused, critical distinctions lost, and, for that matter, lip service paid. This is inevitable in attempting so synoptic a view. In what is surely a graver defect, we have had to omit discussion of the many important dissident subcommunities in sociology, anthropology, economics, and other disciplines, which have sloughed off or never adopted the Standard Social Science Model. In any case, we simply hope that this sketch captures a few things that are true and important, to compensate for the unavoidable simplifying distortions and omissions. Most obviously, there are no pure types in the world, and scholars are quoted not to characterize the full richness of their individual views, which usually undergo considerable evolution over their intellectual development anyway, but rather to illustrate instances of a larger intellectual system. It is the larger intellectual system we are criticizing, and not the multitude of worthwhile research efforts that have gone on inside its structure. We think the roof of the Standard Social Science Model has collapsed, so to speak, because the overall architectural plan is unsound, not because the bricks and other building materials are defective. The detailed research efforts of hundreds of scientists have produced critically important knowledge that has transformed our understanding of the world. In this criticism, we are looking for an architectural design for the social sciences that is worthy of the intelligence and labor of those whose research goes on within their compass.

The Standard Social Science Model's Treatment of Culture

This logic has critically shaped how nearly every issue has been approached and debated in the social sciences. What we are concerned with here, however, is the impact of the Standard Social Science Model on the development of modern conceptions of culture, its causal role in human life, and its relationship to psychology. Briefly, standard views of culture are organized according to the following propositions (see also D. E. Brown, 1991, p. 146; Tooby & Cosmides, 1989a):

1. Particular human groups are properly characterized typologically as having "a" culture, which consists of widely distributed or nearly group-universal behavioral practices, beliefs, ideational systems, systems of significant symbols, or informational substance of some kind. Cultures are more or less bounded entities, although cultural elements may diffuse across boundaries.

2. These common elements are maintained and transmitted "by the group," an entity that has cross-generational continuity.
3. The existence of separate streams of this informational substance, culture, transmitted from generation to generation, is the explanation for human within-group similarities and between-group differences. In fact, all between-group differences in thought and behavior are referred to as cultural differences and all within-group similarities are regarded as the expressions of a particular culture. Since these similarities are considered to be "cultural," they are, either implicitly or explicitly, considered to be the consequence of informational substance inherited jointly from the preceding generation by all who display the similarity.
4. Unless other factors intervene, the culture (like the gene pool) is accurately replicated from generation to generation.
5. This process is maintained through learning, a well-understood and unitary process, that acts to make the child like the adult of her culture.
6. This process of learning can be seen, from the point of view of the group, as a group-organized process called socialization, imposed by the group on the child.
7. The individual is the more or less passive recipient of her culture and is the product of that culture.
8. What is organized and contentful in the minds of individuals comes from culture and is socially constructed. The evolved mechanisms of the human mind are themselves content-independent and content-free and, therefore, whatever content exists in human minds originally derives from the social or (sometimes) nonsocial environment.
9. The features of a particular culture are the result of emergent group-level processes, whose determinants arise at the group level and whose outcome is not given specific shape or content by human biology, human nature, or any inherited psychological design. These emergent processes, operating at the sociocultural level, are the ultimate generator of the significant organization, both mental and social, that is found in human affairs.
10. In discussing culture, one can safely neglect a consideration of psychology as anything other than the nondescript "black box" of learning, which provides the capacity for culture. Learning is a sufficiently specified and powerful explanation for how any behavior acquires its distinct structure and must be the explanation for any aspect of organized human life that varies from individual to individual and from group to group.
11. Evolved, "biological," or "innate" aspects of human behavior or psychological organization are negligible, having been superseded by the capacity for culture. The evolution of the capacity for culture has led to a flexibility in human behavior that belies any significant "instinctual" or innate component (e.g., Geertz, 1973; Montagu, 1968, p. 11; Sahlins, 1976a & b), which, if it existed, would have to reveal itself as robotlike rigid behavioral universals. To the extent that there may be any complex biological textures to individual psychology, these are nevertheless organized and given form and direction by culture and, hence, do not impart any substantial character or content to culture.

On the Reasonableness of the Standard Social Science Model

There are, of course, many important elements of truth in the tenets of the SSSM, both in its core logic and in its treatment of culture. The SSSM would not have become as decisively influential if it did not have a strong surface validity, anchored in important realities. For example: It is true that infants are everywhere the same. Genetic differences are superficial. There is within-group similarity of behavior and there are between-group differences, and these persist across generations, but also change over historical time. Highly organized socially communicated information exists outside of any particular individual at any one time (in the cognitive mechanisms of other individuals), and over time this information can be internalized by the specific individual in question. And so on.

Nevertheless, the Standard Social Science Model contains a series of major defects that act to make it, as a framework for the social sciences, deeply misleading. As a result, it has had the effect of stunting the social sciences, making them seem falsely autonomous from the rest of science (i.e., from the "natural sciences") and precluding work on answering questions that need to be answered if the social sciences are to make meaningful progress as sciences. After a century, it is time to reconsider this model in the light of the new knowledge and new understanding that has been achieved in evolutionary biology, development, and cognitive science since it was first formulated. These defects cluster into several major categories, but we will limit our discussion to the following three:

1. The central logic of the SSSM rests on naive and erroneous concepts drawn from outmoded theories of development. For example, the fact that some aspect of adult mental organization is absent at birth has no bearing on whether it is part of our evolved architecture. Just as teeth or breasts are absent at birth, and yet appear through maturation, evolved psychological mechanisms or modules (complex structures that are functionally organized for processing information) could develop at any point in the life cycle. For this reason, the many features of adult mental organization absent at birth need not be attributed to exposure to transmitted culture, but may come about through a large number of causal avenues not considered in traditional analyses.

2. More generally, the SSSM rests on a faulty analysis of nature-nurture issues, stemming from a failure to appreciate the role that the evolutionary process plays in organizing the relationship between our species-universal genetic endowment, our evolved developmental processes, and the recurring features of developmental environments. To pick one misunderstanding out of a multitude, the idea that the phenotype can be partitioned dichotomously into genetically determined and environmentally determined traits is deeply ill-formed, as is the notion that traits can be arrayed along a spectrum according to the degree that they are genetically versus environmentally caused. The critique of the SSSM that has been emerging from the cognitive and evolutionary communities is not that traditional accounts have underestimated the importance of biological factors relative to environmental factors in human life. Instead, the target is the whole framework that assumes that "biological factors" and "environmental factors" refer to mutually exclusive sets of causes that exist in some kind of explanatory zero-sum relationship, so that the more one explains "biologically" the less there is to explain "socially" or "environmentally." On the contrary,

as we will discuss, environmentalist claims necessarily require the existence of a rich, evolved cognitive architecture.

3. The Standard Social Science Model requires an impossible psychology. Results out of cognitive psychology, evolutionary biology, artificial intelligence, developmental psychology, linguistics, and philosophy converge on the same conclusion: A psychological architecture that consisted of nothing but equipotential, general-purpose, content-independent, or content-free mechanisms could not successfully perform the tasks the human mind is known to perform or solve the adaptive problems humans evolved to solve—from seeing, to learning a language, to recognizing an emotional expression, to selecting a mate, to the many disparate activities aggregated under the term "learning culture" (Cosmides & Tooby, 1987; Tooby & Cosmides, 1989a). It cannot account for the behavior observed, and it is not a type of design that could have evolved.

The alternative view is that the human psychological architecture contains many evolved mechanisms that are specialized for solving evolutionarily long-enduring adaptive problems and that these mechanisms have content-specialized representational formats, procedures, cues, and so on. These richly content-sensitive evolved mechanisms tend to impose certain types of content and conceptual organization on human mental life and, hence, strongly shape the nature of human social life and what is culturally transmitted across generations. Indeed, a post-Standard Model psychology is rapidly coalescing, giving a rapidly expanding empirical foundation to this new framework. In fact, historically, most of the data already gathered by psychologists supports such a view. It required a strongly canalized interpretative apparatus to reconcile the raw data of psychology with the central theoretical tenets of SSSM psychology.

Before examining in detail what is wrong with the SSSM and why the recognition of these defects leads to the formulation of a new model with greater explanatory power, it is necessary first to alleviate the fears of what would happen if one "falls off the edge" of the intellectual world created by the SSSM. These fears have dominated how alternative approaches to the SSSM have been treated in the past and, unless addressed, will prevent alternatives from being fairly evaluated now. Moreover, the Standard Model has become so well-internalized and has so strongly shaped how we now experience and interpret social science phenomena that it will be difficult to free ourselves of the preconceptions that the Standard Model imposes until its Procrustean operations on psychology and anthropology are examined.

THE WORLD BUILT BY THE STANDARD SOCIAL SCIENCE MODEL

The Moral Authority of the Standard Social Science Model

The Case Against Nativism

The overwhelming success of the Standard Social Science Model is attributable to many factors of which, arguably, the most significant has been its widespread moral appeal. Over the course of the century, its strong stand against explaining differences between races, classes, sexes, or individuals by hypothesizing underlying biological differences has been an important element in combating a multitude of searing horrors and oppressions, from the extermination of ethnic groups and the forced sterilization of the poor to restrictive immigration laws and legally institutionalized sex and race discrimination. The depth of these tragedies and the importance of the issues involved have imbued the SSSM and its central precept, "environmentalism," with an imposing moral stature. Consequently, the positions of individual scholars with respect to the SSSM have been taken to imply allegiances with respect to the larger social and moral conflicts around the world. Thus, to support the SSSM was to oppose racism and sexism and to challenge the SSSM was, intentionally or not, to lend support to racism, sexism, and, more generally (an SSSM way of defining the problem), "biological determinism." If biological ideas could be used to further such ends, then ideas that minimized the relevance of biology to human affairs, such as the tenets of the SSSM, could only be to the good.

In this process, all approaches explicitly involving nativist elements of whatever sort became suspect. In consequence, fundamentally divergent—even opposing—programs and claims have become enduringly conflated in the minds of 20th-century social scientists. Most significant was the failure to distinguish adaptationist evolutionary biology from behavior genetics. Although the adaptationist inquiry into our universal, inherited, species-typical design is quite distinct from the behavior genetics question about which differences between individuals or sets of individuals are caused by differences in their genes, the panspecific nativism typical of adaptationist evolutionary biology and the idiotypic nativism of behavior genetics became confused with each other (Tooby and Cosmides, 1990a). Obviously, claims about a complexly organized, universal human nature, by their very character, cannot participate in racist explanations. Indeed, they contradict the central premises of racialist approaches. Yet, despite this fact, adaptationist approaches and behavior genetics remain inextricably intertwined in the minds of the majority of social scientists.

The second strong moral appeal of the Standard Social Science Model derives from its emphasis on human malleability and the hope it, therefore, gave for social melioration or social revolution. The claim of John B. Watson, the founder of behaviorism, exemplifies this optimism about the power of scientifically directed socialization (as well as the usual implicit conflation of idiotypic and panspecific nativism):

> Give me a dozen healthy infants, well-formed, and my own specified world to bring them up in and I'll guarantee to take any one at random and train him to become any type of specialist I might select—doctor, lawyer, artist, merchant-chief, and yes, even beggar-man and thief, regardless of his talents, penchants, tendencies, abilities, vocations, and race of his ancestors (Watson, 1925, p. 82).

As D. E. Brown (1991, p. 61) comments, "In hindsight it is clear that this famous statement about the influence of the environment on individual differences is entirely compatible with the most extreme of the faculty or modular views of the human mind—in which it comprises numerous innate and highly specific mechanisms." But this thought experiment was interpreted by the social science mainsteam, Watson included, as demonstrating that "people are the products of their societies or cultures." Therefore, "change society or culture and you change people. . . . Intelligent, scientific socialization can make us whatever we want to be" (D. E. Brown, 1991, p. 61). Moreover, "[t]he equation of an arch environmentalism (including cultural relativism) with optimism about the practical application of social science to the problems of society remains a force to the present" (D. E. Brown, 1991, p. 62). More critically, the belief that the mind is "almost infinitely malleable" (or, in more modern terms, is a general-purpose computer) means that humans are not condemned to the status quo, and need not inevitably fight wars, or have social classes, or manifest sex-differentiated roles, or live in families, and so on.

If the "happy" ability of the mind to "quite readily take any shape that is presented" (Benedict, 1934/1959, p. 278) is the ameliorator's ideal because it is believed to be logically necessary to allow social change, then dissent from the SSSM tends to be framed as claims about "constraints" or limits on this malleability. This, in turn, is taken to imply a possible intractability to social problems—the stronger the biological forces are, the more we may be constrained to suffer from certain inevitable expressions of human darkness. Thus, the debate on the role of biology in human life has been consistently framed as being between optimistic environmentalists who plan for human betterment and sorrowful, but realistic nativists who lament the unwelcome inevitability of such things as aggression (e.g., Ardrey, 1966; Lorenz, 1966), or who (possibly even gleefully) defend the status quo as inevitable and natural (e.g., Goldberg, 1973, on patriarchy). These nativists are, in turn, "debunked" by the tireless opponents of "biological determinism" (e.g., Chorover, 1979; Lewontin, Rose, & Kamin, 1984; Montagu, 1968, 1978), who place each new biological intrusion onto social science territory in the context of the bitter lessons of the century. (Environmentalist holocausts are, of course, edited out of this chronology.)

This morality play, seemingly bound forever to the wheel of intellectual life, has been through innumerable incarnations, playing itself out in different arenas in different times (rationalism versus empiricism, heredity versus environment, instinct versus learning, nature versus nurture, human universals versus cultural relativism, human nature versus human culture, innate behavior versus acquired behavior, Chomsky versus Piaget, biological determinism versus social determinism, essentialism versus social construction, modularity versus domain-generality, and so on). It is perennial because it is inherent in how the issues have been defined in the SSSM itself, which even governs how the dissidents frame the nature of their dissent. Accordingly, the language of constraint and limitation is usually adopted by biologically oriented behavioral scientists themselves in describing the significance of their own work. Thus we even have titles such as *The Tangled Wing: Biological Constraints on the Human Spirit* (Konner, 1982), *Biological Boundaries of Learning* (Seligman and Hager, 1972), "Constraints on Learning" (Shettleworth, 1972), and "Structural Constraints on Cognitive Development" (Gelman, 1990a). Biologically oriented social and behavioral scientists often see themselves as defining limits on the possible. Environmentalists see themselves as expanding the borders of the possible. As we will see, this framing is profoundly misleading.

Wrong Diagnosis, Wrong Cure

Driven by these fears to an attitude that Daly and Wilson (1988) have termed "biophobia," the social science community lays out implicit and sometimes explicit ground rules in its epistemological hierarchy: The tough-minded and moral stance is to be skeptical of panspecific "nativist" claims; that is, of accounts that refer in any way to the participation of evolved psychological mechanisms together with environmental variables in producing outcomes, no matter how logically inescapable or empirically well-supported they may be. They are thought to be explanations of last resort and, because the tough-minded and skeptical can generate particularistic alternative accounts for any result at will, this last resort is rarely ever actually arrived at. For the same reason, it is deemed to be the moral stance to be correspondingly credulous of "environmentalist" accounts, no matter how vague, absurd, incoherent, or empirically contradicted they may be. These protocols have become second nature (so to speak) to nearly everyone in the social science community. This hierarchy is driven by the fear of falling off the edge of the Standard Social Science Model, into unknown regions where monsters such as "biological" or "genetic determinism" live.

What, in fact, is an environmentalist account? There are two brands of environmentalism: coherent environmentalism and incoherent environmentalism, which correspond approximately to environmentalism as defended and environmentalism as practiced. As Daly and Wilson (1988, p. 8) comment, "[a]ll social theorists, including the staunchest antinativists, seek to describe human nature at some cross-culturally general level of abstraction" and would be "distressed should their theories . . . prove applicable to Americans but not to Papuans." Both Skinner (1957) and Chomsky (1975)—opponents in a paradigmatic case of an environmentalist-nativist debate—posit the existence of universal evolved psychological mechanisms, or what cognitive psychologists have called "innate mechanisms." As Symons (1987) points out, most of what passes for the nature-nurture debate is not about the need to posit evolved mechanisms in theories. Everyone capable of reasoning logically about the problem accepts the necessity of this. As Symons makes clear, what the debate often seems to be about is how general or content-specific the mechanisms are: Skinner proposes conditioning mechanisms that apply to all situations, while Chomsky proposes specialized mechanisms particularly designed for language. Consequently, coherent environmentalists acknowledge that they are positing the existence of evolved developmental or psychological mechanisms and are willing to describe (1) the explicit structure of these mechanisms, and (2) what environmental variables they interact with to produce given outcomes. By this standard, of course, Chomsky is an environmentalist, as was Skinner, as are we, along with most other evolutionary psychologists and evolutionarily informed behavioral scientists. Equally, all coherent behavioral scientists of whatever orientation must be nativists in this same sense, and no coherent and fully specified hypothesis about behavior can avoid making nativist claims about the involvement of evolved structure.

Incoherent environmentalists, on the other hand, are those who propose theories of how environments regulate behavior or even psychological phenomena without describing or even mentioning the evolved mechanisms their theories would require to be complete or coherent. In practice, communities whose rules of discourse are governed by incoherent environmentalism consider any such trend toward explicitness to be introducing vague and speculative variables and—more to the point—to be in bad taste as well. The simple act of providing a complete model is to invoke evolved design and, hence, to court being called a genetic or biological determinist. Given that all coherent (fully specified) models of psychological processes necessarily entail an explication of how environmental variables relate to the inherited architecture or developmental machinery, this attitude has the effect of portraying psychologists who are clear about all causal steps as more soft-minded and speculative than those who remain vague about the crucial elements necessary to make their theories coherent (e.g., Cheng & Holyoak, 1989). (This criticism is, of course, fully symmetrical: Incoherent nativists are those scholars who talk about how evolution structures behavior without attempting to describe the structure of the evolved adaptations that link evolution, environment, and behavior in adaptively patterned ways; for discussion, see Symons, this volume; Tooby & Cosmides, 1990b.)

The problem with an epistemological hierarchy that encourages incoherence and discourages coherence (aside from the fully sufficient objection that it has introduced major distortions into the body of scientific knowledge) is that it is completely unnecessary, even on its own terms. Not only is the cure killing the patient—social science—but also the diagnosis is wrong and the patient is not menaced by the suspected malady. In the first place, as discussed, models of a robust, universal human nature by their very character cannot participate in racist explanations of intergroup differences. This is not just a definitional trick of defining human nature as whatever is universal. There are strong reasons to believe that selection usually tends to make complex adaptations universal or nearly universal, and so humans must share a complex, species-typical and species-specific architecture of adaptations, however much variation there might be in minor, superficial, nonfunctional traits. As long-lived sexual reproducers, complex adaptations would be destroyed by the random processes of sexual recombination every generation if the genes that underlie our complex adaptations varied from individual to individual. Selection in combination with sexual recombination tends to enforce uniformity in adaptations, whether physiological or psychological, especially in long-lived species with an open population structure, such as humans (Tooby & Cosmides, 1990b). Empirically, of course, the fact that any given page out of *Gray's Anatomy* describes in precise anatomical detail individual humans from around the world demonstrates the pronounced monomorphism present in complex human physiological adaptations. Although we cannot yet directly "see" psychological adaptations (except as described neuroanatomically), no less could be true of them. Human nature is everywhere the same.

The Malleability of Psychological Architecture versus the Volatility of Behavioral Outcomes

If the fear that leaving the Standard Social Science Model will lead to racist doctrines is unfounded, what of the issue of human malleability? Does a biologically informed approach necessarily imply an intractability of undesired social and behavioral outcomes and an inevitability of the status quo? After all, isn't the basic thrust of biologically informed accounts against malleability and in favor of constraints and limits on human aspirations?

No. The central premise of an opposition between the mind as an inflexible biological product and the mind as a malleable social product is ill-formed: The notion that inherited psychological structure constrains is the notion that without it we would be even more flexible or malleable or environmentally responsive than we are. This is not only false but absurd. Without this evolved structure, we would have no competences or contingent environmental responsiveness whatsoever. Evolved mechanisms do not prevent, constrain, or limit the system from doing things it otherwise would do in their absence. The system could not respond to "the environment" (that is, to selected parts of the environment in an organized way) without the presence of mechanisms designed to create that connection. Our evolved cognitive adaptations—our inherited psychological mechanisms—are the means by which things are affirmatively accomplished. It is an absurd model that proposes that the potentially unfettered human mind operates by flailing around and is only given structure and direction by the "limits" and "constraints" built in by "biology." Instead, any time the mind generates any behavior at all, it does so by virtue of specific generative programs in the head, in conjunction with the environmental inputs with which they are presented. Evolved structure does not constrain; it creates or enables (Cosmides & Tooby, 1987).

Given that we are all discussing universal human design and if, as Symons argues, all coherent behavioral scientists accept the reality of evolved mechanisms, then the modern nature-nurture debate is really about something else: the character of those evolved mechanisms (Symons, 1987). Does the mind consist of a few, general-purpose mechanisms, like operant conditioning, social learning, and trial-and-error induction, or does it also include a large number of specialized mechanisms, such as a language acquisition device (Chomsky, 1975; Pinker, 1984; Pinker & Bloom, this volume), mate preference mechanisms (Buss, 1989, this volume; Ellis, this volume; Symons, 1979), sexual jealousy mechanisms (Daly, Wilson, & Weghorst, 1982; Wilson & Daly, this volume), mother-infant emotion communication signals (Fernald, this volume), social contract algorithms (Cosmides, 1989; Cosmides & Tooby, 1989, this volume; Gigerenzer & Hug, in press), and so on? This is the point of separation between the Standard Social Science Model and the Integrated Causal Model, and it is the main focus of this volume.

How, then, does the issue of the number and specificity of evolved mental mechanisms bear on the issue of the inevitability of undesired behavioral outcomes? As we will discuss and review later, the same answer applies: General mechanisms turn out to be very weak and cannot unassisted perform at least most and perhaps all of the tasks humans routinely perform and need to perform. Our ability to perform most of the environmentally engaged, richly contingent activities that we do depends on the guiding presence of a large number of highly specialized psychological mechanisms (Cosmides & Tooby, 1987; Rozin, 1976; Symons, 1987; Tooby & Cosmides, 1990b). Far from constraining, specialized mechanisms enable competences and actions that would not be possible were they absent from the architecture. This rich array of cognitive specializations can be likened to a computer program with millions of lines of code and hundreds or thousands of functionally specialized subroutines. It is because of, and not despite, this specificity of inherent structure that the output of computational systems is so sensitively contingent on environmental inputs. It is just this sensitive contingency to subtleties of environmental variation that make a narrow intractability of outcomes unlikely.

The image of clay, and terms such as "malleability," "flexibility," and "plasticity" confuse two separate issues: (1) the detailed articulation of human evolved psychological design (i.e., what is the evolved design of our developmental programs and of the mechanisms they reliably construct), and (2) the fixity or intractability of expressed outcomes (what must people do, regardless of circumstance). The first question asks what evolved organization exists in the mind, while the second asks what events will inevitably occur in the world. Neither "biology," "evolution," "society," or "the environment" directly impose behavioral outcomes, without an immensely long and intricate intervening chain of causation involving interactions with an entire configuration of other causal elements. Each link of such a chain offers a possible point of intervention to change the final outcome. For this reason, computer programs present a far better model of the situation: The computer does nothing without them, they frequently involve superbly complex contingent branching and looping alternatives, they can (and the procedures in the human mind certainly do) take as input environmental variables that create cascading changes in subsequent computational events and final outcomes, and the entire system may respond dramatically and dynamically to direct intervention (for example, the alteration of even a single instruction) at any of a great number of locations in the program.

Moreover, we know in advance that the human psychological system is immensely flexible as to outcome: Everything that every individual has ever done in all of human history and prehistory establishes the minimum boundary of the possible. The maximum, if any, is completely unknown. Given the fact that we are almost entirely ignorant of the computational specifics of the hundreds or thousands of mechanisms that comprise the human mind, it is far beyond the present competence of anyone living to say what are and are not achievable outcomes for human beings.

It is nevertheless very likely to be the case that we will find adaptive specializations in the human mind that evolved to make, under certain circumstances, choices or decisions that are (by most standards) ethically unacceptable and often lead to consensually undesirable outcomes (e.g., male sexual proprietariness, Wilson & Daly, this volume; discriminative parental solicitude, Daly & Wilson, 1981; Mann, this volume). If one is concerned about something like family violence, however, knowing the details of the mechanisms involved will prove crucial in taking any kind of constructive or ameliatory action. "Solutions" that ignore causation can solve nothing.

In any case, the analysis of the morality or practicality of intervention to prevent undesired outcomes—"ontogenetic engineering" (Daly, Wilson & Weghorst, 1982)—is beyond the scope of this discussion. Our point here is simply that leaving behind the SSSM does not entail accepting the inevitability of any specific outcome, nor does it entail the defense of any particular aspect of the status quo. Instead, for those genuinely concerned with such questions, it offers the only realistic hope of understanding enough about human nature to eventually make possible successful intervention to bring about humane outcomes. Moreover, a program of social melioration carried out in ignorance of human complex design is something like letting a blindfolded individual loose in an operating room with a scalpel—there is likely to be more blood than healing. To cure, one needs to understand; lamenting disease or denouncing the researchers who study its properties has never yet saved a life. At present, we are decades away from having a good model of the human mind, and this is attributable in no small measure to a misguided antinativism that has, for many, turned from being a moral stance into a tired way of defending a stagnated and sterile intellectual status quo. There are, of course, no guarantees, and it is at least logically possible that understanding our complex array of evolved mechanisms will offer no way to improve the human condition. But, if that is the case, it will be the first time in history that major sets of new discoveries turned out to be useless.[3]

The Empirical Authority of the Standard Social Science Model

The Division of Labor: Content-Independent Psychology

One major consequence of the adoption of the Standard Social Science Model has been the assignment of a division of labor among the social sciences. It gave each field its particular mission, stamped each of them with its distinctive character, and thereby prevented them from making much progress beyond the accumulation of particularistic knowledge. Anthropology, as well as sociology and history, study both the important and variable content of human life (the signal) and the more vaguely defined processes and contingent events that generated it (the artificer or author of the signal). Psychology studies the medium on which this socially generated content is inscribed, the process of inscription, and the mechanisms that enable the inscription to take place. (The SSSM also assigns to psychology and to psychological anthropology the task of cataloging, at the individual level, the particularistic psychological phenomena that are created by the action of each culture on individuals; e.g., what do American college sophomores get anxious about?).

In advance of any data, the Standard Model defined for psychology the general character of the mechanisms that it was supposed to find (general-purpose, content-independent ones), its most important focus (learning), and how it would interpret the data it found (no matter what the outcome, the origin of content was to be located externally—for example, in the unknowably complex unobserved prior history of the individual—and not "internally" in the mind of the organism). Psychologists certainly were not forced by the character of their data into these types of conclusions (e.g., Breland & Breland, 1961). Instead, they had to carefully design their experiments so as to exclude evolutionarily organized responses to biologically significant stimuli by eliminating such stimuli from their protocols (e.g., by using stimulus-impoverished Skinner boxes or the currently widespread practice of eliminating "emotionally charged" stimuli from cognitive experiments). This was done in the name of good experimental design and with the intention of eliminating contaminating "noise" from the exploration of the content-independent mechanisms that were thought to exist.

The Division of Labor: Particularistic, Content-Specific Anthropology

Even more than psychology, anthropology was shaped by the assumptions inherent in the SSSM's division of labor: A content-independent (or content-free) psychology symbiotically requires a content-supplying anthropology to provide the agent—culture—that transforms malleable generalized potential into specifically realized human beings. So anthropology's mission was to study the particular (Geertz, 1973, p. 52). Consequently, anthropology became the custodian of the key explanatory concept in the paradigm, "culture." Belief in culture, as a substance passed across generations causing the richly defined particularity of adult mental and social organization defines one's membership in the modern social science community. The invocation of culture became the universal glue and explanatory variable that held social science explanations together: Why do parents take care of their children? It is part of the social role their culture assigns to them. Why are Syrian husbands jealous? Their culture tied their status to their wife's honor. Why are people sometimes aggressive? They learn to be because their culture socializes them to be violent. Why are there more murders in America than in Switzerland? Americans have a more individualistic culture. Why do women want to look younger? Youthful appearance is valued in our culture. And so on.

Although using culture as an all-purpose explanation is a stance that is difficult or impossible to falsify, it is correspondingly easy to "confirm." If one doubts that the causal agent for a particular act is transmitted culture, one can nearly always find similar prior acts (or attitudes, or values, or representations) by others, so a source of the contagion can always be identified. Culture is the protean agent that causes everything that needs explaining in the social sciences, apart from those few things that can be explained by content-general psychological laws, a few drives, and whatever superorganic processes (e.g., history, social conflict, economics) that are used to explain the particularities of a specific culture. Psychologists, then, need not explain the origin of complexly specific local patterns of behavior. They can be confident that anthropologists have done this job and have tracked, captured, defined, and analyzed the causal processes responsible for explaining why men are often sexually jealous or why women often prefer to look youthful.

In defining culture as the central concept of anthropology, the SSSM precluded the development of the range of alternative anthropologies that would have resulted if, say, human nature, economic and subsistence activity, ecological adaptation, human universals, the organization of incentives inside groups, institutional propagation, species-typical psychology, or a host of other reasonable possibilities had been selected instead. More critically, because of the way in which the SSSM frames the relationship between culture and the human mind, anthropology's emphasis on relativity and explanatory particularism becomes inescapable, by the following logic: If the psyche is general-purpose, then all organized content comes from the outside, from culture. Therefore, if something is contentful, then it must be cultural; if it is cultural, then—by the nature of what it is to be cultural—it is plastically variable; if it is plastically variable, then there can be no firm general laws about it. Ergo, there can be no general principles about the content of human life (only the contentless laws of learning). The conclusion is present in the premises. The relativity of human behavior, far from being the critical empirical discovery of anthropology (Geertz, 1973, 1984), is something imposed *a priori* on the field by the assumptions of the SSSM, because its premises define a program that is incapable of finding anything else. Relativity is no more "there" to be found in the data of anthropologists than a content-independent architecture is "there" to be found in the data of psychologists. These conclusions are present in the principles by which these fields approach their tasks and organize their data, and so are not "findings" or "discoveries" at all.

The consequences of this reasoned arrival at particularism reverberate throughout the social sciences, imparting to them their characteristic flavor, as compared with the natural sciences. This flavor is not complexity, contingency, or historicity: Sciences from geology to astronomy to meteorology to evolutionary biology have these in full measure. It is, instead, that social science theories are usually provisional, indeterminate, tentative, indefinite, enmeshed in an endlessly qualified explanatory particularism, for which the usual explanation is that human life is much more complex than mere Schrödinger equations or planetary ecosystems. Because culture was held to be the proximate (and probably the ultimate) cause of the substance and rich organization of human life, the consensus was, naturally, that documenting its variability and particularity deserved to be the primary focus of anthropological study (e.g., Geertz, 1973). This single proposition alone has proven to be a major contributor to the failure of the social sciences (Tooby & Cosmides, 1989a). Mainstream sociocultural anthropology has arrived at a situation resembling some nightmarish short story Borges might have written, where scientists are condemned by their unexamined assumptions to study the nature of mirrors only by cataloging and investigating everything that mirrors can reflect. It is an endless process that never makes progress, that never reaches closure, that generates endless debate between those who have seen different reflected images, and whose enduring product is voluminous descriptions of particular phenomena.

The Empirical Disproof of a Universal Human Nature

The view that the essence of human nature lies in its variousness and the corresponding rejection of a complex, universal human nature is not advanced by anthropologists simply as an assertion. Instead, it is presented as a dramatic and empirically well-supported scientific discovery (Geertz, 1984) and is derived from a particular method through which the limits of human nature are explored and defined. This method, a logical process of elimination, "confirmed" that the notion of human nature was empirically almost vacuous. Since infants are everywhere the same, then anything that varies in adults can only (it was reasoned) be cultural and, hence, socially inherited and, hence, socially manufactured. The method depends on accepting the premise that behavior can only be accounted for in these two ways: (1) as something "biological," or inborn, which is, therefore, inflexibly rigid regardless of environment and (because of the psychic unity of humankind) everywhere the same, or (2) as sociocultural, which includes everything that varies, at a minimum, and perhaps many things that happen by accident to be universal as well.

Whenever it is suggested that something is "innate" or "biological," the SSSM-oriented anthropologist or sociologist riffles through the ethnographic literature to find a report of a culture where the behavior (or whatever) varies (for a classic example, see Mead's 1949 *Male and Female*). Upon finding an instance of reported variation (or inventing one through strained interpretation; see again, Mead, 1949), the item is moved from the category of "innate," "biological," "genetically determined," or "hardwired" to the category of "learned," "cultural," or "socially constructed." Durkheim succinctly runs through the process, discussing why sexual jealousy, filial piety, and paternal love must be social constructions, despite claims to the contrary: "History, however, shows that these inclinations, far from being inherent in human nature, are often totally lacking. Or they may present such variations in different human societies that the residue obtained after eliminating all these differences—which alone can be considered of psychological origin—is reduced to something vague and rudimentary and far removed from the facts that need explanation" (Durkheim, 1895/1962, p. 106). Because almost everything human is variable in one respect or another, nearly everything has been subtracted from the "biologically determined" column and moved to the "socially determined" column. The leftover residue of "human nature," after this process of subtraction has been completed, is weak tea indeed, compared to the rich and engaging list of those dimensions of life where humans vary. No wonder Geertz (1973) finds such watered-down universals no more fundamental or essential to humans than the behaviors in which humans vary. Psychologists have, by and large, accepted the professional testimony of anthropologists and have, as part of their standard intellectual furniture, the confidence that other cultures violate virtually every universal claim about the content of human life. (D. E. Brown [1991] offers a pivotal examination of the history and logic of anthropological approaches to human universals, cultural variation, and biology, and this entire discussion is informed by his work.)

Discovering Regularities Depends on Selecting Appropriate Frames of Reference

Because of the moral appeal of antinativism, the process of discrediting claims about a universal human nature has been strongly motivated. Anthropologists, by each new claim of discovered variability, felt they were expanding the boundaries of their discipline (and, as they thought, of human possibility itself) and liberating the social sciences from biologically deterministic accounts of how we are inflexibly constrained to live as we do. This has elevated particularism and the celebration of variability to central values inside of anthropology, strongly asserted and fiercely defended.

The most scientifically damaging aspect of this dynamic has not been the consequent rhetorical emphasis most anthropologists have placed on the unusual (Bloch, 1977; Goldschmidt, 1960; Symons, 1979; see, especially, D. E. Brown, 1991). As Bloch (1977, p. 285) says, it is the "professional malpractice of anthropologists to exaggerate the exotic character of other cultures." Nor is the most damaging aspect of this dynamic the professionally cultivated credulousness about claims of wonders in remote parts of the world, which has led anthropologists routinely to embrace, perpetuate, and defend not only gross errors (see Freeman, 1983, on Mead and Samoa; Suggs, 1971, on Linton and the Marquesas) but also obvious hoaxes (e.g., Casteneda's UCLA dissertation on Don Juan; or the gentle "Tasaday," which were manufactured by officials of the Marcos regime).

The most scientifically damaging aspect of this value system has been that it leads anthropologists to actively reject conceptual frameworks that identify meaningful dimensions of cross-cultural uniformity in favor of alternative vantage points from which cultures appear maximally differentiated. Distinctions can easily be found and endlessly multiplied, and it is an easy task to work backward from some particular difference to find a framework from which the difference matters (e.g., while "mothers" may exist both there and here, motherhood here is completely different from motherhood there because mothers there are not even conceptualized as being blood kin, but rather as the wife of one's father, etc., etc.). The failure to view such variation as always profoundly differentiating is taken to imply the lack of a sophisticated and professional appreciation of the rich details of ethnographic reality.

But whether something is variable or constant is not just "out in the world"; it is also a function of the system of categorization and description that is chosen and applied. The distance from Paris to Mars is complexly variable, so is the location of Paris "constant" and "inflexible" or is it "variable?" In geography, as in the social sciences, one can get whichever answer one wants simply by choosing one frame of reference over another. The order that has been uncovered in physics, for example, depends on the careful selection of those particular systems of description and measure that allow invariances to appear. These regularities would all disappear if physicists used contingently relative definitions and measures, such as their own heartbeat to count units of time (the speed of light would slow down every time the measurer got excited—"relativity" indeed).

Other sciences select frameworks by how much regularity these frameworks allow them to uncover. In contrast, most anthropologists are disposed to select their frameworks so as to bring out the maximum in particularity, contingency, and variability (e.g., how are the people they study unique?). Certainly one of the most rewarded of talents inside anthropology is the literary ability to express the humanly familiar and intelligible as the exotic (see, e.g., Geertz's description of a raid by the authorities on a cock fight in Bali; Geertz, 1973; see D. E. Brown, 1991, for a lucid dissection of the role of universals in this example, and Barkow, 1989, on how Balinese cock fighting illustrates the conventional psychology of prestige). Anthropologists' attraction to frameworks that highlight particularistic distinctions and relationships has nearly precluded the accumulation of genuine knowledge about our universal design and renders anthropologists' "empirically" grounded dismissal of the role of biology a matter of convention and conjuring rather than a matter of fact.

Beneath Variable Behavior Lie Universal Mechanisms

The social science tradition of categorizing everything that varies as "nonbiological" fails to identify much that is "biological." This is because anthropologists have chosen ill-suited frames of reference (such as those based on surface "behavior" or reflective "meaning") that accentuate variability and obscure the underlying level of universal evolved architecture. There may be good reasons to doubt that the "behavior" of marriage is a cross-cultural universal or that the articulated "meaning" of gender is the same across all cultures, but there is every reason to think that every human (of a given sex) comes equipped with the same basic evolved design (Tooby & Cosmides, 1990a). The critical question is not, for example, whether every human male in every culture engages in jealous behaviors or whether mental representations attached to situations of extra-pair mating are the same in every culture; instead, the most illuminating question is whether every human male comes endowed with developmental programs that are designed to assemble (either conditionally or regardless of normal environmental variation) evolutionarily designed sexual jealousy mechanisms that are then present to be activated by appropriate cues. To discern and rescue this underlying universal design out of the booming, buzzing confusion of observable human phenomena requires selecting appropriate analytical tools and frames of reference.

Genetics, for example, had enormous difficulty making progress as a science until geneticists developed the distinction between genotype and phenotype—between the inherited basis of a trait and its observable expression. We believe a similar distinction will prove necessary to the development of an integrated social science. We will refer to this as the distinction between the *evolved* (as in evolved mechanisms, evolved psychology, evolved architecture, etc.) and the *manifest* (as in manifest psychology, manifest behavior, etc.). One observes variable manifest psychologies or behaviors between individuals and across cultures and views them as the product of a common, underlying evolved psychology, operating under different circumstances. The mapping between the evolved architecture and manifest behavior operates according to principles of expression that are specified in the evolved developmental mechanisms and the psychological mechanisms they reliably construct; manifest expressions may differ between individuals when different environmental inputs are operated on by the same procedures to produce different manifest outputs (Cosmides & Tooby, 1987; Tooby & Cosmides, 1989b).

For example, some individuals speak English while others do not, yet everyone passes through a life stage when the same species-typical language acquisition device is activated (Pinker & Bloom, this volume). In fact, if an individual survives a childhood of aberrant social isolation she may never acquire a language and may be incapable of speaking; yet, she will have had the same species-typical language acquisition device as everyone else. So what at the behavioral level appears variable ("speaks English," "speaks Kikuyu"; or, even, "speaks a language," "does not speak any language") fractionates into variable environmental inputs and a uniform underlying design, interacting to produce the observed patterns of manifest variation. The fog enveloping most social science debates would blow away if all hypotheses were completely spelled out, through analyzing each situation into environmental conditions, evolved architecture, and how their interaction produces the manifest outcome.

Standard Model partisans have confidently rested their empirical case on what now appears to be uncertain ground: that manifest universality across cultures is the observation that evolutionary hypotheses about human nature require and that, on the other hand, cross-cultural variability establishes that the behavior in question is uncontaminated by "biology" and is, instead, solely the product of "culture" or "social processes." The recognition that a universal evolved psychology will produce variable manifest behavior given different environmental conditions exposes this argument as a complete non sequitur. From a perspective that describes the whole integrated system of causation, the distinction between the biologically determined and the nonbiologically determined can be seen to be a nondistinction.

In its place, the relevant distinction can be drawn between what Mayr (among others) called open and closed behavior programs (Mayr, 1976). This terminology distinguishes mechanisms that are open to factors that commonly vary in the organism's natural environment and, hence, commonly vary in their manifest expression from those that are closed to the influence of such factors and are, consequently, uniform in their manifest expression. The human language acquisition device is an open behavior program whose constructed product, adult competency in the local language, varies depending on the language community in which the individual is raised. Certain facial emotional displays that manifest themselves uniformly cross-culturally (Ekman, 1973) may be examples of closed behavior programs. The Standard Social Science Model's method of sorting behavior by its cross-cultural uniformity or variability of expression into "biologically determined" and "socially determined" categories in reality sorts behaviors into those generated by closed behavior programs, and those generated by open behavior programs. In neither case can the analysis of the "determination" of behavior be made independent of "biology," that is, independent of understanding the participation of the evolved architecture. For this reason, the whole incoherent opposition between socially determined (or culturally determined) phenomena and biologically determined (or genetically determined) phenomena should be consigned to the dustbin of history, along with the search for a biology-free social science.

The Search for the Artificer

If psychology studies the content-independent laws of mind and anthropology studies the content-supplying inheritances of particular cultures, one still needs to find the content-determining processes that manufacture individual cultures and social systems. The Standard Social Science Model breaks the social sciences into schools (materialist, structural-functionalist, symbolic, Marxist, postmodernist, etc.) that are largely distinguished by how each attempts to affirmatively characterize the artificer, which they generally agree is an emergent group-level process of some kind. It is far beyond the scope of this chapter to review and critique these attempts to discover somewhere in the social system what is in effect a generative computational system. Nevertheless, it is important to recognize that the net effect of the central logic of the Standard Social Science Model has been to direct the quest for the ultimate cause or generator of significant mental and social organization outward away from the rich computational architecture of the human mind. It is there where sufficiently powerful ordering processes—ones capable of explaining the phenomena—are primarily to be found. As will be discussed later, it is there where the actual generators of organization are principally (though not exclusively) located and could be productively investigated. And understanding this architecture is an indispensible ingredient in modeling or understanding whatever super-individual processes exist.

This is not to say that there aren't many important phenomena and processes operating at the population level, which, for example, modify the nature and distribution of representations (for non-SSSM analyses, see, e.g., Sperber, 1985, 1990, on epidemiological approaches to cultural transmission; see also Boyd & Richerson, 1985; Campbell, 1965, 1975; Durham, 1991; and others, who examine analogs to natural selection operating at the cultural level). But because the traditional SSSM efforts to characterize these generative processes make them entirely external to "the individual" as well as independent of species-typical psychology, these accounts tend to share a certain ineradicable indefiniteness of location and substance. The SSSM attempt to abstract social processes away from the matrix of interacting psychological architectures necessarily fails because the detailed structure of psychological mechanisms is inextricably bound up in how these social processes operate. One might say that what mostly remains, once you have removed from the human world everything internal to individuals, is the air between them. This vagueness of ontology and causal mechanism makes it difficult to situate these hypothetical generative processes with respect to our knowledge of the rest of the natural world (Sperber, 1986). Moreover, attempting to locate in these population-level processes the primary generator of significant organization has caused these processes to be fundamentally misunderstood, mystified, and imbued with such unwarranted properties as autonomy, teleology, functionality, organism-like integration, intelligence, intentionality, emotions, need-responsiveness, and even consciousness (see, e.g., Durkheim, 1895/1962; Harris, 1979; Kroeber, 1915; Marx, 1867/1909; Merton, 1949; Parsons, 1949; Radcliffe-Brown, 1952; see Harris, 1968, for review and discussion).

Of course, the social system is not like a person or an organism or a mind, self-ordering due to its own functionally integrated mechanisms. It is more like an ecosystem or an economy whose relationships are structured by feedback processes driven by the dynamic properties of its component parts. In this case, the component parts of the population are individual humans, so any social dynamics must be anchored in models of the human psychological architecture. In contrast, the customary insistence on the autonomy (or analytic separability) of the superorganic level is why there have been so few successful or convincing causal models of population-level social processes, including models of culture and social organization (apart from those originating in microeconomics or in analogies drawn from population biology, which do not usually take SSSM-style approaches; see, e.g., Boyd & Richerson, 1985; Schelling, 1978).

Rejecting the design of individuals as central to the dynamics is fatal to these models, because superorganic (that is, population-level) processes are not just "out there," external to the individual. Instead, human superindividual interactions depend intimately on the representations and other regulatory elements present in the head of every individual involved and, therefore, on the systems of computation inside each head. These govern what is selected from "out there," how this is represented, what procedures act on the representations, and what behaviors result that others can then observe and interact with in a population dynamic fashion (Sperber, 1985, 1986, 1990;

Tooby & Cosmides, 1989a). These psychological mechanisms are primarily where there is sufficient anti-entropic computational power to explain the rich patterning of human life. The design of the human psychological architecture structures the nature of the social interactions humans can enter into, as well as the selectively contagious transmission of representations between individuals. Only after the description of the evolved human psychological architecture has been restored as the centerpiece of social theory can the secondary anti-entropic effects of population-level social dynamics be fully assessed and confidently analyzed. Hence, the study of population-level social and cultural dynamics requires a sophisticated model of human psychology to undergird it (see Barkow, 1989, this volume; Cosmides & Tooby, 1989, this volume; Daly, 1982; Sperber, 1985, 1990; Tooby & Cosmides, 1989a).

The Division of Labor: The Social Sciences versus the Natural Sciences

The single most far-reaching consequence of the Standard Social Science Model has been to intellectually divorce the social sciences from the natural sciences, with the result that they cannot speak to each other about much of substance. Where this divorce has been achieved can be precisely located within the model. Because biology and evolved psychology are internal to the individual and because culture—the author of social and mental organization—is seen as external to the individual, the causal arrow from outside to inside logically insulates the social sciences from the rest of the natural sciences, making them autonomous and the natural sciences substantively irrelevant. This set of propositions is the locus of the primary break between the social and the natural sciences. Although there has been a causal flow across four billion years of evolutionary time, its ability to causally shape the human present is impermeably dammed at the boundaries of the individual—in fact, well within the individual, for evolution is thought to provide nothing beyond an account of the origins of the drives, if any, and of the general-purpose, content-free learning or computational equipment that together comprise the SSSM's minimalist model of human nature.

Thus, whatever their empirical success may be, the claims made by (to pick some obvious examples) ethologists, sociobiologists, behavioral ecologists, and evolutionary psychologists about the evolutionary patterning of human behavior can be simply dismissed out of hand as wrong, without requiring specific examination, because causality does not flow outward from the individual or from psychology, but inward from the social world (Sahlins, 1976a). Or, as Durkheim put it nearly a century before, "every time that a social phenomenon is directly explained by a psychological phenomenon, we may be sure that the explanation is false" (Durkheim, 1895/1962, p. 103). Organic evolution manufactured the biological substratum, the human capacity for culture—"the breadth and indeterminateness of [man's] inherent capacities" (Geertz, 1973, p. 45)—but otherwise reaches a dead end in its causal flow and its power to explain.

Finally, it would be a mistake to think that the Standard Social Science Model reflects the views solely of social scientists and is usually resisted by biologists and other natural scientists. It is instead considered the common sense and common decency of our age. More particularly, it is a very useful doctrine for biologists themselves to hold. Many of them vigorously defend its orthodoxies, adding their professional imprimatur to the social scientists' brief for the primacy of culture or social forces over "biology" (see, e.g., Gould, 1977a, 1977b; Lewontin, Rose & Kamin, 1984). This does not happen simply because some are drawn to the formidable moral authority of the Standard Model and the mantle it confers. Even for those of a genuinely scientific temperament, fascinated with biological phenomena for their own sake, such a doctrine is a godsend. The Standard Model guarantees them, *a priori*, that their work cannot have implications that violate socially sanctified beliefs about human affairs because the Standard Model assures them that biology is intrinsically disconnected from the human social order. The Standard Model therefore frees those in the biological sciences to pursue their research in peace, without having to fear that they might accidentally stumble into or run afoul of highly charged social or political issues. It offers them safe conduct across the politicized minefield of modern academic life. This division of labor is, therefore, popular: Natural scientists deal with the nonhuman world and the "physical" side of human life, while social scientists are the custodians of human minds, human behavior, and, indeed, the entire human mental, moral, political, social, and cultural world. Thus, both social scientists and natural scientists have been enlisted in what has become a common enterprise: the resurrection of a barely disguised and archaic physical/mental, matter/spirit, nature/human dualism, in place of an integrated scientific monism.

THE EVOLUTIONARY CONTRIBUTION TO INTEGRATED EXPLANATION

Rediscovering the Relevance of Evolutionary Biology

If the adoption of the Standard Social Science Model has not led to a great deal of natural science-like progress, that is surely not a good argument against it. Its convenience has no bearing on whether it is true. What, then, are the reasons for believing it is false? There are a number of major problems that independently lead to the rejection of the SSSM—some emerging from evolutionary biology, some from cognitive science, and some from their integration. We will discuss three of these problems, arguing that (1) the Standard Social Science Model's analysis of developmental or "nature-nurture" issues is erroneous; (2) the general-purpose, content-free psychology central to the SSSM could not have been produced by the evolutionary process and, therefore, is not a viable candidate model of human psychology; and (3) a psychology of this kind cannot explain how people solve a whole array of tasks they are known to routinely perform.

For advocates of the Standard Social Science Model, evolution is ignored because it is irrelevant: The explanatory power of evolution ends with the emergence of the content-free computational equipment that purportedly constitutes human nature. This equipment does not impose any form on the social world, but instead acquires all of its content from the social world. The supposed erasure of content-sensitive and content-imparting structure from hominid psychological architecture during our evolution is what justifies the wall of separation between the natural and the social sciences. If this view were correct, then evolution would indeed be effectively irrelevant to the social sciences and the phenomena they study.

In contrast, proponents of the Integrated Causal Model accept that, in addition to whatever content-independent mechanisms our psychological architecture may contain, it also contains content-specific devices, including those computationally responsible for the generation and regulation of human cultural and social phenomena. These content-specific mechanisms are adaptations (as are content-independent mechanisms), and evolved to solve long-enduring adaptive problems characteristic of our hunter-gatherer past. Because of their design, their operation continually imparts evolutionarily patterned content to modern human life. If this view is correct, then the specifics of evolutionary biology have a central significance for understanding human thought and action. Evolutionary processes are the "architect" that assembled, detail by detail, our evolved psychological and physiological architecture. The distinctive characteristics of these processes are inscribed in the organizational specifics of these designs. Consequently, an understanding of the principles that govern evolution is an indispensable ally in the enterprise of understanding human nature and an invaluable tool in the discovery and mapping of the species-typical collection of information-processing mechanisms that together comprise the human mind. The complex designs of these mechanisms are the main causal channels through which the natural sciences connect to and shape the substance of the "social" sciences.

Thus, the relevance of evolutionary biology does not in the least depend on our being "just like" other species, which we obviously are not (Tooby & DeVore, 1987). Each species has its own distinctive properties stemming from its own unique evolutionary history. Evolutionary biology is fundamentally relevant to the study of human behavior and thought because our species is the product of naturalistic terrestrial processes—evolutionary processes—and not of divine creation or extraterrestrial intervention. However unusual our properties may be from a zoological point of view—and we have every reason to believe humans followed a unique evolutionary trajectory (Tooby & DeVore, 1987)—we need an account of how they were produced in the natural world of causation over evolutionary history (Boyd & Richerson, 1985). Such accounts are constructed from (1) the principles that govern the evolutionary process (such as natural selection and drift), (2) the designs of ancestral hominid species, and (3) the particular ancestral environments and contingent historical events hominids encountered during their evolutionary history.

Reproduction, Feedback, and the Construction of Organic Design

> [T]hese elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us. These laws, taken in the largest sense, being . . . Reproduction; Inheritance which is almost implied by reproduction; Variability . . . and as a consequence . . . Natural Selection. . . .
>
> —CHARLES DARWIN,
> *The Origin of Species*

While physicists tend to start their causal history with the Big Bang, biologists usually select a different, later event: the emergence of the first living organism. Life (or the instances we have so far observed) is a phenomenon that originated on earth three to four billion years ago through the formation of the first living organism by contingent physical and chemical processes. What is life? What defining properties qualified some ancient physical system as the first living organism? From a Darwinian perspective, it is the reproduction by systems of new and similarly reproducing systems that is the defining property of life. An organism is a self-reproducing machine. All of the other properties of living organisms—cellular structure, ATP, polypeptides, the use of carbon's ability to form indefinitely large chains, DNA as a regulatory element—are incidental rather than essential, and the logic of Darwinism would apply equally to self-reproducing robots, to self-reproducing plasma vortices in the sun, or to anything else that reproduces with the potential for inheritable change (mutation). From reproduction, the defining property of life, the entire elegant deductive structure of Darwinism follows (Dawkins, 1976; Tooby & Cosmides, 1990b; Williams, 1985).

Very simple proto-bacteria emerged early in terrestrial history, as chemical machines that constructed additional chemical machines like themselves. Because reproduction means the construction of offspring designs like the parent machines, one could imagine this leading to an endless chain of proliferating systems identical to the original parent. This is not what happened, of course, because mutations or random modifications are sometimes introduced into offspring designs by accident, with far-reaching consequences. Most random modifications introduce changes into the organism's organization that interfere with the complex sequence of actions necessary for self-reproduction. But a small proportion of random modifications happen to cause an enhancement in the average ability of the design to cause its own reproduction. In the short run, the frequency of those variants whose design promotes their own reproduction increases, and the frequency of those variants whose design causes them to produce fewer (or no) offspring decreases. Consequently, one of two outcomes usually ensues: (1) the frequency of a design will drop to zero—i.e., go extinct (a case of negative feedback); or (2) a design will outreproduce and thereby replace all alternative designs in the population (a case of positive feedback). After such an event, the population of reproducing machines is different from its ancestors because it is equipped with a new and more functionally organized design or architecture. Thus, the fact that alternative design features give rise to reproductive performance differences creates the system of positive and negative feedback called natural selection. Natural selection guides the incorporation of design modifications over generations according to their consequences on their own reproduction.

Over the long run, down chains of descent, this cycle of chance modification and reproductive feedback leads to the systematic accretion within architectures of design features that promote or formerly promoted their own propagation. Even more importantly, the reproductive fates of the inherited properties that coexist in the same organism are linked together: What propagates one design feature tends to propagate others (not perfectly, but sufficiently for a coherent design to emerge; see Cosmides & Tooby, 1981). This means that traits will be selected to work together to produce the same outcomes and to enhance each other's functionality. Frequently, then, these accumulating properties will sequentially fit themselves together into increasingly functionally elaborated machines for reproduction, composed of constituent mechanisms—called adaptations—that solve problems that are either necessary for reproduction or increase its likelihood (Darwin, 1859; Dawkins, 1986; R. Thornhill, 1991; Tooby & Cosmides, 1990b; Williams, 1966, 1985). As if by the handiwork of an invisible and nonforesightful engineer, element after element is added to a design over generations, making it a more functional system for propagation under the conditions prevailing at the time each new element was added. At present, there is no extant alternative theory for how organisms acquired complex functional organization over the course of their evolution (Dawkins, 1986).

What is most compelling about Darwin's approach is that the process of natural selection is an inevitable by-product of reproduction, inheritance, and mutation. Like water running downhill, over generations organisms tend to flow into new functional designs better organized for effective propagation in the environmental context in which they evolved. There is, however, another method, besides selection, by which mutations can become incorporated into species-typical design: chance. The sheer impact of many random accidents may cumulatively propel a useless mutation upward in frequency until it crowds out all alternative design features from the population. Its presence in the architecture is not explained by the (nonexistent) functional consequences it has on reproduction, and so it will not be coordinated with the rest of the organism's architecture in a functional way.

But despite the fact that chance plays some role in evolution, organisms are not primarily chance agglomerations of stray properties. To the extent that a feature has a significant effect on reproduction, selection will act on it. For this reason, important and consequential aspects of organismic architectures are shaped by selection. By the same token, those modifications that are so minor that their consequences are negligible on reproduction are invisible to selection and, therefore, are not organized by it. Thus, chance properties drift through the standard designs of species in a random way, unable to account for complex organized design and, correspondingly, are usually peripheralized into those aspects that do not make a significant impact on the functional operation of the system (Tooby & Cosmides, 1990a, 1990b).

In short, evolution (or descent with modification, to use Darwin's phrase) takes place due to the action of both chance and natural selection, causing descendants to diverge in characteristics from their ancestors, down chains of descent. Over evolutionary time, this appears as a succession of designs, each a modification of the one preceding it. Generation by generation, step by step, the designs of all of the diverse organisms alive today—from redwoods and manta rays to humans and yeast—were permuted out of the original, very simple, single-celled ancestor through an immensely long sequence of successive modifications. Each modification spread through the species either because it caused its own propagation, or by accident. Through this analytic framework, living things in general and each species in particular can be located in the principled causal history of the universe. Moreover, the specific design features of a species' architecture can also be causally located in this history: they exist either because of chance incorporation or because they contributed to the functional operation of the architecture. The theory of evolution by natural selection vastly expanded the range of things that could be accounted for, so that not only physical phenomena such as stars, mountain ranges, impact crater's, and alluvial fans could be causally located and explained but also things like whales, eyes, leaves, nervous systems, emotional expressions, and the language faculty.

The modern Darwinian theory of evolution consists of the logically derivable set of causal principles that necessarily govern the dynamics of reproducing systems, accounting for the kinds of properties that they cumulatively acquire over successive generations. The explicit identification of this core logic has allowed the biological community to develop an increasingly comprehensive set of principles about what kinds of modifications can and do become incorporated into the designs of reproducing systems down their chains of descent, and what kinds of modifications do not (Dawkins, 1976, 1982, 1986; Hamilton, 1964, 1972; Maynard Smith, 1964, 1982; Williams, 1966). This set of principles has been tested, validated, and enriched by a comprehensive engagement with the empirical reality of the biological world, from functional and comparative anatomy, to biogeography, to genetics, to immunology, to embryology, to behavioral ecology, and so on. Just as the fields of electrical and mechanical engineering summarize our knowledge of principles that govern the design of human-built machines, the field of evolutionary biology summarizes our knowledge of the engineering principles that govern the design of organisms, which can be thought of as machines built by the evolutionary process (for good summaries, see Daly & Wilson 1984a; Dawkins, 1976, 1982, 1986; Krebs & Davies, 1987). Modern evolutionary biology constitutes, in effect, an "organism design theory." Its principles can be used both to evaluate the plausibility of the psychology posited by the Standard Social Science Model and to guide the construction of a better successor psychology.

The Peculiar Nature of Biological Functionality

In certain narrowly delimited ways, then, the spontaneous process of evolution parallels the intentional construction of functional machines by human action. But, whereas machines built by human engineers are designed to serve a diverse array of ends, the causal process of natural selection builds organic machines that are "designed" to serve only one very specialized end: the propagation into subsequent generations of the inherited design features that comprise the organic machine itself.

Because design features are embodied in organisms, they can, generally speaking, propagate themselves in only two ways: (1) by solving problems that will increase the probability that the organism they are situated in will produce offspring, or (2) by solving problems that will increase the probability that the organism's kin will produce offspring (Hamilton, 1964; Williams & Williams, 1957). An individual's relatives, by virtue of having descended from a common ancestor, have an increased likelihood of having the same design feature as compared to other conspecifics, so their increased reproduction will tend to increase the frequency of the design feature. Accordingly, design features that promote both direct reproduction and kin reproduction, and that make efficient trade-offs between the two, will replace those that do not. To put this in standard biological terminology, design features are selected for to the extent that they promote their inclusive fitness (Hamilton, 1964). For clarity, we will tend to call this propagation or design-propagation.

Selection, then, is the only known account for the natural occurrence of complexly organized functionality in the inherited design of undomesticated organisms. Moreover, selection can only account for functionality of a very narrow kind: approximately, design features organized to promote the reproduction of an individual and his or her relatives (Dawkins, 1986; Williams, 1966). Fortunately for the modern theory of evolution, the only naturally occurring complex functionality that has ever been documented in plants, animals, or other organisms is functionality of just this kind, along with its derivatives and by-products. Mammals evolved adaptations to produce milk to feed their own young, infectious micro-organisms mimic human biochemistry to escape immune surveillance so they can survive and reproduce, and plants produce oxygen as a waste product of feeding themselves through photosynthesis, and not for the pleasure of watching humans breathe or forests burn. Of course, human breeders artificially intervene, and one could easily imagine, as an alternative to a Darwinian world, a benevolent deity or extraterrestrial being creating the properties of living things in order to serve human convenience rather than the organisms' own reproduction. Wild horses could be born with saddle-shaped humps, luggage racks, and a spontaneous willingness to be ridden; chronic bacterial infections could jolt humans with caffeine every morning 45 seconds before they need to get up. Similarly, the nonliving world could be full of intricate functional arrangements not created by humans, such as mountains that naturally mimic hotels down to the details of closet hangers, electric wiring, and television sets. But this is not the world we live in. We live in a world of biological functionality and its derivatives, traceable originally to the operation of natural selection on reproducing systems (Darwin, 1859; Dawkins, 1976, 1986). To be able to understand the world of biological phenomena, one must be able to recognize this peculiar functional organization and distinguish it from the products of chance.

Of course, the fact that living things are machines organized to reproduce themselves and their kin does not mean that evolutionary functional analysis focuses narrowly on such issues as copulation or pregnancy (things intuitively associated with reproduction) over, say, taste preferences, vision, emotional expression, social categorization, coalition formation, or object recognition. A life history of successfully achieved reproduction (including kin reproduction) requires accomplishing the entire tributary network of preconditions for and facilitations of reproduction in complex ecological and social environments. Of course, this includes all of the information-gathering, inference, and decision-making that these tasks entail. For this reason, humans display a diverse range of adaptations designed to perform a wide and structured variety of subsidiary tasks, from solicitation of assistance from one's parents, to language acquisition, to modeling the spatial distribution of local objects, to reading the body language of an antagonist.

Finally, the behavior of individual organisms is caused by the structure of their adaptations and the environmental input to them; it is not independently governed by the principle of individual fitness maximization. Individual organisms are best thought of as adaptation-executers rather than as fitness-maximizers. Natural selection cannot directly "see" an individual organism in a specific situation and cause behavior to be adaptively tailored to the functional requirements imposed by that situation. To understand the role of selection in behavior, one must follow out all steps in the chain: Selection acting over evolutionary time has constructed the mechanisms we have inherited in the present, and it is this set of mechanisms that regulates our behavior—not natural selection directly. These mechanisms situated in particular individuals frequently—but by no means always—bring about a functional coordination between the adaptive demands of particular situations and associated behavioral responses.

Thus, the biological concept of functionality differs from the folk notion of functionality as goal-seeking behavior. Although some of our evolved psychological mechanisms probably operate through goal-seeking, surely none of them has fitness-maximization as a mentally represented goal (see Symons, this volume). Those goal-seeking mechanisms that do exist most likely embody proximate goals, such as "stay warm" or "protect your infant," rather than ultimate goals, such as "maximize your fitness" or "have as many offspring as possible." Indeed, goals of the latter kind are probably impossible to instantiate in any computational system (Symons, 1987, 1989, this volume; see also Barkow, 1989; Cosmides & Tooby, 1987, 1992; Daly & Wilson, 1988; Irons, 1983, p. 200; Tooby & Cosmides, 1990b. For somewhat contrary views, see, e.g., Alexander, 1979, 1987 and Turke, 1990).

For this reason, an adaptationist approach does not properly involve explaining or interpreting *individual* behavior in specific situations as "attempts" to increase fitness (Symons, 1989, this volume; Tooby & Cosmides, 1990b). To make the distinction between these alternative views of evolutionary explanation clear—humans as fitness-maximizers (fitness-teleology) versus humans as adaptation-executors (adaptationism)—a brief example will serve. Fitness teleologists may observe a situation and ask something like, "How is Susan increasing her fitness by salting her eggs?" An adaptationist would ask, instead, "What is the nature of the evolved human salt preference mechanisms—if any—that are generating the observed behavior and how did the structure of these mechanisms mesh with the physiological requirements for salt and the opportunities to procure salt in the Pleistocene?" So, in viewing cases of behavior, the adaptationist question is not, "How does this or that action contribute to this particular individual's reproduction?" Instead, the adaptationist questions are, "What is the underlying panhuman psychological architecture that leads to this behavior in certain specified circumstances?" and "What are the design features of this architecture—if any—that regulate the relevant behavior in such a way that it would have constituted functional solutions to the adaptive problems that regularly occurred in the Pleistocene?

What Adaptations Look Like

For the reasons outlined above, the species-typical organization of the psychology and physiology of modern humans necessarily has an evolutionary explanation and an evolutionarily patterned architecture. This is not a vague speculation or an overreaching attempt to subsume one discipline inside another, but constitutes as solid a fact as any in modern science. In fact, this conclusion should be a welcome one because it is the doorway through which a very rich body of additional knowledge—evolutionary biology—can be brought to bear on the study of psychological architecture. At its core, the discovery of the design of human psychology and physiology is a problem in reverse engineering: We have working exemplars of the design in front of us, but we need to organize our sea of observations about these exemplars into a map of the causal structure that accounts for the behavior of the system. Psychology has never been limited by a lack of observations. Fortunately, the knowledge that humans are the product of evolution supplies us with a powerful set of tools—the concepts of evolutionary functional analysis—for organizing these observations into useful categories so that the underlying systems of order can be discerned.

The most illuminating level of description for organizing observations about living species is usually in terms of their adaptations (and associated evolutionary categories). This system of description has some warrant on being considered a privileged frame of reference because the complex functional organization that exists in the design of organisms was injected into them through the construction of adaptations by natural selection. Adaptations are the accumulated output of selection, and selection is the single significant anti-entropic or ordering force orchestrating functional organic design (Dawkins, 1986). So if one is interested in uncovering intelligible organization in our species-typical psychological architecture, discovering and describing its adaptations is the place to begin.

To understand what complex adaptations "look like," it will help to begin concretely with a standard example, the vertebrate eye and its associated neural circuitry. (For its role in understanding adaptations, see Pinker & Bloom, this volume; for a discussion of color vision, see Shepard, this volume.) The eye consists of an exquisitely organized arrangement of cells, structures, and processes, such as (1) a transparent protective outer coating, the cornea; (2) an opening, the pupil, through which light enters; (3) an iris, which is a muscle that surrounds the pupil and constricts or dilates the aperture, regulating the amount of light entering the eye; (4) a lens, which is both transparent and flexible, and whose curvature and thickness can be adjusted to bring objects of varying distances into focus; (5) the retina, a light-sensitive surface that lies in the focal plane of the lens: this multilayered neural tissue lining the inside back of the eyeball is, in effect, a piece of the brain that migrated to the eye during fetal development; (6) classes of specialized cells (rods and cones) in the retina that transform sampled properties of ambient light through selective photochemical reactions into electrochemical impulses; (7) the activation by these electrochemical impulses of neighboring bipolar cells, which, in turn, feed signals into neighboring ganglion cells, whose axons converge to form the optic nerve; (8) the optic nerve, which carries these signals out of the eye and to the lateral geniculate bodies in the brain; (9) the routing of these signals to the visual cortex, into a series of retinotopic maps and other neural circuits, where they are further analyzed by a formidable array of information-processing mechanisms that also constitute crucial parts of the visual system.

The dynamic regulatory coordination present in the operation of the eye is also striking: The variable aperture modulates the amount of light entering the eye in coordination with ambient illumination; the eyes are stereoscopically coordinated with each other so that their lines of vision converge on the same object or point of interest; the thickness and curvature of the lens is modulated so that light from the object being viewed is focused on the retina and not in front of it or behind it; and so on. Through a more detailed description, this list could easily be extended to include many thousands of specialized features that contribute to the functionality of the system (tear ducts, eyelids, edge detectors, muscle systems, specific photochemical reactions, and so on) through the orchestrated arrangement of hundreds of millions of cells. This is even more true if we were to go beyond a taxonomically generalized description of the vertebrate eye and relate specific design features in particular vertebrates to the particular environments and visual tasks they faced. Frogs, for example, have retinal "bug detectors"; the rabbit retina has a variety of specialized devices, including a "hawk detector" (Marr, 1982, p. 32), and so on. It is important to appreciate that this organization is not just macroscopic, but extends down to the organized local relationships that subsets of cells maintain with each other, which perform such computations as edge detection and bug detection—and beyond, down into the specific architecture of the constituent cells themselves. Thus, rods and cones have a distinctive design and layout that includes specialized organelles that adjust the size and shape of the photoreactive regions; they have membranes that fold back on themselves to form sacs localizing the photoreceptive pigments; they have specialized chemistry so that light induces these pigments to undergo chemical changes that ultimately result in a change of membrane potential; they are arranged so that this change of membrane potential effects the release of neurotransmitters to neighboring bipolar glion cells, and so on.

Thus, the eye is an extraordinarily complex arrangement of specialized features that does something very useful for the organism. Moreover, this structure was originally absent from the ancestral design of the original single-celled founding organism, so the appearance of eyes in modern organisms must be explained as a succession of modifications across generations away from this initial state. It is easy to see how selection, through retaining those accidental modifications that improved performance, could start with an initial accidentally light-sensitive nerve ending or regulatory cell and transform it, through a large enough succession of increasingly complex functional forms, into the superlatively crafted modern eye (see, e.g., Dawkins, 1986). In fact, eyes (light-receptive organs) have evolved independently over 40 times in the history of animal life from eyeless ancestral forms (Mayr, 1982).

Of course, there are certainly many nonselectionist processes in evolution by which descendants are modified away from ancestral forms—drift, macromutation, hitchhiking, developmental by-product, and so on. But selection is the only process that directs change by retaining variants that are more functional. Thus, selection is the only causal process that has a systematic tendency to propel the system in the direction of increasingly functional arrangements, instead of into the immeasurably larger array of nonfunctional arrangements that the system could move to at each of the innumerable choice points in the evolution of designs. In contrast, nonselectional processes can produce functional outcomes only by chance because a new modification's degree of functionality plays no role in determining whether nonselectional processes will cause it to be retained or eliminated. For this reason, evolutionary processes other than selection are properly classified as "chance processes" with respect to the evolution of adaptive complexity. It would be a coincidence of miraculous degree if a series of these function-blind events, brought about by drift, by-products, hitchhiking, and so on, just happened to throw together a structure as complexly and interdependently functional as an eye (Dawkins, 1986; Pinker & Bloom, this volume). For this reason, nonselectionist mechanisms of evolutionary change cannot be seen as providing any reasonable alternative explanation for the eye or for any other complex adaptation. Complex functional organization is the signature of selection.

The eye is by no means a unique case. Immunologists, for example, have traced out a similar, immensely articulated architecture of complexly interrelated defenses (the blood monocytes, histiocytes, free macrophages, T-lymphocytes, B-lymphocytes, spleen, thymus, and so on). In fact, virtually every organ that has been examined so far betrays a complex functionality unmatched as of yet by any system engineered by humans. More than a century of research and observation confirms that selection builds into organisms a complex functional organization of an eye-like precision and quality.

Still, although many social and biological scientists are willing to concede that the body is full of the most intricately functional machinery, heavily organized by natural selection, they remain skeptical that the same is true of the mind. Moreover, partisans of the Standard Social Science Model insist on the Cartesian distinction between the material world of anatomy and physiology and the mental world of psychology, vigorously resisting attempts to see them as different descriptions of the same integrated system, subject to the same organizing principles. Arguments by Chomsky and others that our psychological architecture should contain "mental organs" for the same reasons that the rest of the body contains physical organs (i.e., that different tasks require functionally different solutions) have yet to convince the majority of psychologists outside of perception and language (Chomsky, 1975; Marshall, 1981).

Thus, Lewontin is expressing a thoroughly orthodox SSSM skepticism toward the idea that the human psychological architecture is functionally organized when he suggests that "[h]uman cognition may have developed as the purely epiphenomenal consequence of the major increase in brain size, which, in fact, may have been selected for quite other reasons" (Lewontin, 1990, p. 244). At least as numerous are those researchers who detect in human thought and behavior something more than the sheer accident that Lewontin sees, and yet who ask: Aren't psychological (or neurophysiological) mechanisms expected to be less well-engineered than physiological organs? High degrees of functionality are all very well for eyes, intestines, and immune systems, but what about the constituent structures of the human psychological architecture? Are there at least any examples of well-engineered psychological adaptations that might parallel physiological adaptations?

What is most ironic about this question is that perhaps the single most uncontroversial example of an adaptation—an example that is conceded to be well-engineered by even the most exercised of the anti-adaptationists—*is* a psychological adaptation: the eye. As Epicharmus pointed out two and half millennia ago, "Only mind has sight and hearing; all things else are deaf and blind." The eye and the rest of the visual system perform no mechanical or chemical service for the body; it is an information-processing adaptation. This information-processing device is designed to take light incident on a two-dimensional body surface and—through applying information-processing procedures to this two-dimensional array—construct cognitive models of the local three-dimensional world, including what objects are present, their shapes, their locations, their orientations, their trajectories, their colors, the textures of their surfaces, as well as face recognition, emotional expression recognition, and so on. Indeed, for those committed to a Cartesian world view, one could think of the eye as a tube that traverses metaphysical realms, one end of which obtrudes into the physical realm, the other into the mental. For modern monists, however, these two realms are simply alternative descriptions of the same thing, convenient for different analytic purposes. The "mental" consists of ordered relationships in physical systems that embody properties typically running under labels such as "information," "meaning," or regulation. From this point of view, there is no Cartesian tube: both ends of the visual system are physical and both are mental.

Because psychologists as a community have been resistant to adaptationist thinking, it was an enormous (although nonaccidental) stroke of good fortune that the visual system extrudes a "physical end" to the surface of the body and that this "physical end" bears a remarkable resemblance to the camera, a functional machine designed by humans. Selection has shaped the physical structure of the eye so that it reflects and exploits the properties of light, the geometry of the three-dimensional world, the refracting properties of lenses, and so on; the camera has a similar structure because it was designed by human engineers to reflect and exploit these same properties. These parallels between camera and eye were clues that were so obvious and so leading that it became a reasonable enterprise to investigate the visual system from a functionalist perspective. Researchers started with the physical end and followed the "Cartesian tube" upward and inward, so to speak, into the mind. In so doing, they have discovered increasingly complex and specialized computational machinery: edge detectors, motion detectors, shape detectors, depth boundary detectors, bug detectors (in the third neural layer of the retina of frogs), stereoscopic disparity analyzers, color constancy mechanisms, face recognition systems, and on and on.

Hundreds of vision researchers, working over decades, have been mapping this exquisitely structured information-processing adaptation, whose evolutionary function is scene analysis—the reconstruction of models of real-world conditions from a two-dimensional visual array. As more and more functional subcomponents are explored, and as artificial intelligence researchers try to duplicate vision in computational systems attached to electronic cameras, four things have become clear (Marr, 1982; Poggio, Torre, & Koch, 1985). The first is that the magnitude of the computational problem posed by scene analysis is immensely greater than anyone had suspected prior to trying to duplicate it. Even something so seemingly simple as perceiving the same object as having the same color at different times of the day turns out to require intensely specialized and complex computational machinery because the spectral distribution of light reflected by the object changes widely with changes in natural illumination (Shepard, this volume). The second conclusion is that as a psychological adaptation (or set of adaptations, depending on whether one is a lumper or splitter), our visual system is very well-engineered, capable of recovering far more sophisticated information from two-dimensional light arrays than the best of the artificially engineered systems developed so far. The third is that successful vision requires specialized neural circuits or computational machinery designed particularly for solving the adaptive problem of scene analysis (Marr, 1982). And the fourth is that scene analysis is an unsolvable computational problem unless the design features of this specialized machinery "assume" that objects and events in the world manifest many specific regularities (Shepard, 1981, 1984, 1987a; Marr, 1982; Poggio et al., 1985). These four lessons—complexity of the adaptive information-processing problem, well-engineered problem-solving machinery as the evolved solution, specialization of the problem-solving machinery to fit the particular nature of the problem, and the requirement that the machinery embody "innate knowledge" about the problem-relevant parts of the world—recur throughout the study of the computational equipment that constitutes human psychology (Cosmides & Tooby, 1987, 1992; Tooby & Cosmides, 1989a, 1990b; on language, see Chomsky, 1975; Pinker, 1989; on vision, see Marr, 1982; Poggio et al., 1985).

These discoveries of superlative "engineering" in the visual system have been paralleled in the study of the other sense organs, which are simply the recognizable transducing ends of an intricate mass of psychological adaptations that consist of increasingly more complex and integrative layers of specialized neural processing. For a variety of reasons, the information-processing adaptations involved in perception have been the only psychological mechanisms that have been studied for decades and in depth from a functionalist perspective. Contributing factors include the fact that their functionality is obvious to all sensate humans and their scientific study was rescued from the metaphysical doubt that hangs over other psychological phenomena because their associated physical transducing structures provided a "materialist" place to begin. Arguably the most important factor, however, was that these were the only mechanisms for which psychologists had any good standards of what counted as biologically successful problem-solving. Unacquainted with evolutionary biology, few psychologists know that there are standards for successful problem-solving in other realms as well, such as social behavior. Unless one knows what counts as a biologically successful outcome, one simply cannot recognize or investigate complex functional design or assess the extent to which a design is well-engineered.

Consequently, at present it is difficult to assess how well psychological adaptations measure up against the intricacy and functionality of other adaptations. We can only judge on the basis of the restricted set that have already been studied extensively from a functionalist perspective—the perceptual mechanisms. Of course, because the paradigmatic example of a well-engineered adaptation, used for over 130 years in biology, is a psychological adaptation, we know that in at least some cases our evolved information-processing machinery incorporates complex functional design of the highest order. Indeed, when the eye does appear in debates over Darwinism, it is usually used by anti-Darwinians, who insist that the eye is far too perfect a mechanism to have been constructed by natural selection. In general, whenever information-processing mechanisms have been studied from an evolutionary functional perspective—human vision and audition, echolocation in bats, dead-reckoning in desert ants, and so on—the results have indicated that the brain/mind contains psychological adaptations at least as intricately functional as anything to be found in the rest of the body.

One could perhaps argue that perceptual mechanisms are exceptional cases because they are evolutionarily older than those psychological adaptations that are distinctively human-specific, and so have had more time to be refined. There are many reasons to suspect this is not the case. But, even if it were, it would only suggest that purely human-specific adaptive problems, such as extensive tool use or extensive reciprocation, would have problem-solving adaptations less exquisite than vision, hearing, maternal care, threat-perception, motivational arbitration, mate selection, foraging, emotional communication, and many other problems that have been with us for tens of millions of years. It would not mean that we have no adaptations to human-specific problems at all. One reason the case of language is so illuminating is that it speaks to exactly this issue of the potential for complex functionality in human-specific adaptations. The language faculty is the only human information-processing system outside of perception that has been studied extensively with clear standards of what counts as functional performance, and the facts of psycholinguistics weigh in heavily against the hypothesis that human-specific adaptations have had insufficient time to evolve the same highly elaborated, intricately interdependent functionality characteristic of perceptual mechanisms (Pinker & Bloom, this volume). The language faculty has the same hallmarks of overwhelmingly functional complex design that the visual system does, and yet we know it is a recent and human-specific adaptation that evolved after the hominids split off from the (rest of the) great apes (Pinker & Bloom, this volume). The claim that language competence is a simple and poorly engineered adaptation cannot be taken seriously, given the total amount of time, engineering, and genius that has gone into the still unsuccessful effort to produce artificial systems that can remotely approach—let alone equal—human speech perception, comprehension, acquisition, and production.

Finally, behavioral scientists should be aware that functional organic machines look very different from the kinds of systems human engineers produce using planning and foresight. Human engineers can start with a clean drawing board, designing systems from scratch to perform a function cleanly, using materials selected particularly for the task at hand. Evolving lineages are more like the proverbial ship that is always at sea. The ship can never go into dry dock for a major overhaul; whatever improvements are made must be implemented plank by plank, so that the ship does not sink during its modification. In evolution, successive designs are always constructed out of modifications of whatever preexisting structures are there—structures linked (at least in the short run) through complex developmental couplings. Yet these short-run limitations do not prevent the emergence of superlatively organized psychological and physiological adaptations that exhibit functionality of the highest known order—higher, in fact, than human engineers have been able to contrive in most cases. This is because the evolutionary process continues to operate over large numbers of individuals and over enormous stretches of time, with selection relentlessly hill-climbing. To anthropomorphize, selection achieves its results through "tinkering," saving large numbers of frequently small and independent improvements cumulatively over vast expanses of time (Jacob, 1977). Thus, chains of successive modifications may be very large indeed to arrive at an increasingly sophisticated "solution" or problem-solving mechanism. The fact that alternative modifications are randomly generated—and that selection at any one time is limited to choosing among this finite set of actual alternatives—means that the evolutionary process might by chance "overlook" or "walk by" a specific solution that would have been obvious to a human engineer, simply because the correct mutations did not happen to occur. The fact that evolution is not a process that works by "intelligence" cuts both ways, however. Precisely because modifications are randomly generated, adaptive design solutions are not precluded by the finite intelligence of any engineer. Consequently, evolution can contrive subtle solutions that only a superhuman, omniscient engineer could have intentionally designed.

So, although organisms are functionally designed machines, they look very different from the machines that humans build. For this reason, the science of understanding living organization is very different from physics or chemistry, where parsimony makes sense as a theoretical criterion. The study of organisms is more like reverse engineering, where one may be dealing with a large array of very different components whose heterogeneous organization is explained by the way in which they interact to produce a functional outcome. Evolution, the constructor of living organization, has no privileged tendency to build into designs principles of operation that are simple and general. Evolution operates by chance—which builds nothing systematic into organisms—and by selection—which cumulatively adds modifications, regardless of whether they add complexity. Thus, psychologists are not likely to find a few satisfying general principles like Maxwell's equations that unify all psychological phenomena, but instead a complex pluralism of mechanisms. Satisfying general principles will instead be found at the next level up, in the principles of evolutionary functionalism that explain the organization of these mechanisms. At an engineering or mechanism level, knowledge will have to be constructed mechanism by mechanism, with the organization of the properties of each mechanism made intelligible by knowing the specific evolved function of that mechanism. Thus, the computational mechanisms that generate maternal love, grammar acquisition, mate selection, kin-directed assistance, or reciprocation can be expected to parallel Ramachadran's characterization of perception as,

> essentially a "bag of tricks;" that through millions of years of trial and error, the visual system evolved numerous short-cuts, rules-of-thumb and heuristics which were adopted not for their aesthetic appeal or mathematical elegance but simply because they *worked* (hence the "utilitarian" theory). This is a familiar idea in biology but for some reason it seems to have escaped the notice of psychologists, who seem to forget that the brain is a biological organ just like the pancreas, the liver, or any other specialized organ (Ramachadran, 1990, p. 24).

Adaptations, By-products, and Random Effects

The most fundamental analytic tool for recognizing an adaptation is its definition. Stripped of complications and qualifications, an adaptation is (1) a system of inherited and reliably developing properties that recurs among members of a species that (2) became incorporated into the species' standard design because during the period of their incorporation, (3) they were coordinated with a set of statistically recurrent structural properties outside the adaptation (either in the environment or in the other parts of the organism), (4) in such a way that the causal interaction of the two (in the context of the rest of the properties of the organism) produced functional outcomes that were ultimately tributary to propagation with sufficient frequency (i.e., it solved an adaptive problem for the organism). (For a more extensive definition of the concept of *adaptation*, see Tooby & Cosmides, 1990b). Adaptations are mechanisms or systems of properties crafted by natural selection to solve the specific problems posed by the regularities of the physical, chemical, developmental, ecological, demographic, social, and informational environments encountered by ancestral populations during the course of a species' or population's evolution (for other discussions of adaptation, see Pinker & Bloom, this volume; Symons, 1989, this volume; R. Thornhill, 1991; Tooby & Cosmides, 1990a; Williams, 1966, 1985; see Dawkins, 1986, for his discussion of adaptations under the name *adaptive complexity*).

Thus, chance and selection, the two components of the evolutionary process, explain different types of design properties in organisms, and all aspects of design must be attributed to one of these two forces. Complex functional organization is the product and signature of selection. Reciprocally, the species-typical properties of organisms attributable to chance will be no more important, organized, or functional than can be attributed to chance. The conspicuously distinctive cumulative impacts of chance and selection allow the development of rigorous standards of evidence for recognizing and establishing the existence of adaptations and distinguishing them from the nonadaptive aspects of organisms caused by the nonselectionist mechanisms of evolutionary change (Pinker & Bloom, this volume; Symons, this volume; R. Thornhill, 1991; Tooby & Cosmides, 1990b; Williams, 1966, 1985). Complex adaptations are usually species-typical (Tooby & Cosmides, 1990a); moreover, they are so well-organized and such good engineering solutions to adaptive problems that a chance coordination between problem and solution is effectively ruled out as a plausible explanation. Adaptations are recognizable by "evidence of special design" (Williams, 1966); that is, by recognizing certain features of the evolved species-typical design of an organism "as components of some special problem-solving machinery" (Williams, 1985, p. 1) that solve an evolutionarily long-standing problem. Standards for recognizing special design include factors such as economy, efficiency, complexity, precision, specialization, and reliability, which, like a key fitting a lock, render the design too good a solution to a defined adaptive problem to be coincidence (Williams, 1966). Like most other methods of empirical hypothesis testing, the demonstration that something is an adaptation is always, at the core, a probability assessment concerning how likely a situation is to have arisen by chance. The lens, pupil, iris, optic nerve, retina, visual cortex, and so on, are too well coordinated both with each other and with environmental factors—such as the properties of light and the reflectant properties of surfaces—to have arisen by chance.

In addition to adaptations, the evolutionary process commonly produces two other outcomes visible in the designs of organisms: (1) concomitants or by-products of adaptations (recently nicknamed "spandrels"; Gould & Lewontin, 1979); and (2) random effects. The design features that comprise adaptations became incorporated into the standard design because they promoted their own frequency and are, therefore, recognizable by their organized and functional relationships to the rest of the design and to the structure of the world. In contrast, concomitants of adaptations are those properties of the phenotype that do not contribute to functional design per se, but that happen to be coupled to properties that are, and so were dragged along into the organism's design because of selection on the design features to which they are linked. They may appear organized, but they are not *functionally* organized.

The explanation for any specific concomitant or spandrel is, therefore, the identification of the adaptation or adaptations to which it is coupled, together with the reason why it is coupled. For example, bones are adaptations, but the fact that they are white is an incidental by-product. Bones were selected to include calcium because it conferred hardness and rigidity to the structure (and was dietarily available), and it simply happens that alkaline earth metals appear white in many compounds, including the insoluble calcium salts that are a constituent of bone. From the point of view of functional design, by-products are the result of "chance," in the sense that nothing in the process of how they came to be incorporated into a design other than sheer coincidence would cause them to be coordinated solutions to any adaptive problem. For this reason, by-products are expected not to contribute to the solution of adaptive problems more often or more effectively than chance could explain. Finally, of course, entropic effects of many types act to introduce functional disorder into the design of organisms. They are recognizable by the lack of coordination that they produce within the architecture or between it and the environment, as well as by the fact that they frequently vary between individuals. Classes of entropic processes include mutation, evolutionarily unprecedented environmental change, individual exposure to unusual circumstances, and developmental accidents. Of course, one can decompose organisms into properties (or holistic relations) according to any of an infinite set of alternative systems. But, unless one applies a categorization system designed to capture their functional designs or adaptations, organisms will seem to be nothing but spandrels, chemistry, and entropy.

Recognizing Psychological Adaptations: Evolutionary, Cognitive, Neural, and Behavioral Levels of Analysis

Capturing Invariance in Functional Organization: Behavioral, Cognitive, and Neuroscience Descriptions

If the psychological architectures of organisms are infused with complex functional organization, this is not always easy to see. Precisely because functional organization may be very complex, and embedded in an even more bewildering array of variable and intricate by-products, it may appear to the unaided intellect to be indistinguishable from chaos or poor design. Unless one knows what to look for—unless, at the very least, one knows what counts as functional—one cannot recognize complex functionality even when one sees its operation.

Sciences prosper when researchers discover the level of analysis appropriate for describing and investigating their particular subject: when researchers discover the level where invariance emerges, the level of underlying order. What is confusion, noise, or random variation at one level resolves itself into systematic patterns upon the discovery of the level of analysis suited to the phenomena under study.

How, then, should the psychological architectures of organisms be described so as to capture a level of underlying functional order? Three different languages for describing psychological phenomena are commonly used: the behavioral, the cognitive, and the neurobiological. Each language has strengths and weaknesses for different scientific purposes. For the purpose of discovering, analyzing, and describing the functional organization of our evolved psychological architecture, we propose that the information-processing language of cognitive science is the most useful.

In the first place, this is because the evolutionary function of the brain is the adaptive regulation of behavior and physiology on the basis of information derived from the body and from the environment. Alternative design features are selected for on the basis of how well they solve adaptive problems—problems whose solution affects reproduction. How an organism processes information can have an enormous impact on its reproduction. It is, therefore, meaningful to ask what kind of cognitive design features would have constituted good solutions to adaptive information-processing problems that persisted over many generations. Evolutionary biology and hunter-gatherer studies supply definitions of the recurrent adaptive problems humans faced during their evolution, and cognitive psychology describes the information-processing mechanisms that evolved to solve them. By combining insights from these two fields, the functional organization of the mind can be brought into sharp relief.

Second, adaptations are usually species-typical. Consequently, to capture evolved functional organization, one needs a language that can describe what is invariant across individuals and generations. This process of description is key: By choosing the wrong descriptive categories, everything about an organism can seem variable and transitory to the extent that "plasticity" or "behavioral variability" can seem the single dominant property of an organism. In contrast, well-chosen categories can bring out the hidden organization that reappears from individual to individual and that, consequently, allows psychological phenomena to be described both economically and precisely.

Purely behavioral categories are seldom able to capture meaningful species-typical uniformity: Are humans "aggressive" or "peaceful," "pair-bonding" or "polygynous," "rational" or "irrational?" With much justice, Geertz, echoing Kroeber, dismissed large and vague behavioral universals, such as marriage and religion, as "fake" (1973, p. 101). Human phenomena accurately described and categorized solely in terms of behavioral outcomes appear endlessly variable; they seem to manifest a kaleidoscopic welter of erratic and volatile phenomena, which makes any underlying uniformity—let alone functional design—difficult to see. Exceptions, such as reflexes and fixed action patterns, occur in the very few cases where the mapping between stimulus and behavior is simple and immediate. Behavioral characterizations of anything much more complicated rapidly become so watered down with exceptions that, at best, one ends up with vague portrayals employing terms such as "capacity," "predisposition," "urge," "potential," and so on—things too murky to be helpful either in describing adaptations or in predicting behavior.

Perhaps more important, however, is that behavior is not a phenomenon *sui generis*. It is the product of mechanisms that process information. Mechanisms that produce behavior can be usefully studied on a variety of different descriptive and explanatory levels. Neuroscientists describe the brain on a physical level—as the interaction of neurons, hormones, neurotransmitters, and other organic aspects. In contast, cognitive psychologists study the brain as an information-processing system—that is, as a collection of programs that process information—without reference to the exact neurophysiological processes that perform these tasks. A cognitive description specifies what kinds of information the mechanism takes as input, what procedures it uses to transform that information, what kinds of data structures (representations) those procedures operate on, and what kinds of representations or behaviors it generates as output. The study of cognition is the study of how humans and other animals process information.

To understand subsequent arguments clearly, it is important to keep in mind exactly what we mean by the cognitive or information-processing level. Like all words, "cognitive" is used to mean many different things. For example, some researchers use it in a narrow sense, to refer to so-called "higher mental" processes, such as reasoning, as distinct from other psychological processes, such as "emotion" or "motivation"; that is, to refer to a concept that corresponds more or less to the folk notion of reasoning while in a calm frame of mind. In contrast, we are using the word *cognitive* in a different and more standard sense. In this chapter, we use terms such as *cognitive* and *information-processing* to refer to a language or level of analysis that can be used to precisely describe any psychological process: Reasoning, emotion, motivation, and motor control can all be described in cognitive terms, whether the processes that give rise to them are conscious or unconscious, simple or complex. In cognitive science, the term *mind* refers to an information-processing description of the functioning of an organism's brain and that is the sense in which we use it. (For a more detailed discussion of the nature of cognitive explanations, see Block, 1980; Fodor, 1981; or Pylyshyn, 1984.)

For example, ethologists have traditionally studied very simple cognitive programs. A newborn herring gull, for instance, has a cognitive program that defines a red dot on the end of a beak as salient information from the environment, and that causes the chick to peck at the red dot upon perceiving it. Its mother has a cognitive program that defines pecking at her red dot as salient information from her environment, and that causes her to regurgitate food into the newborn's mouth when she perceives its pecks. These simple programs adaptively regulate how herring gulls feed their young. (If there is a flaw anywhere in these programs—i.e., if the mother or chick fails to recognize the signal or to respond appropriately—the chick starves. If the flaw has a genetic basis, it will not be passed on to future generations. By such feedback, natural selection shapes the design of cognitive programs.)

These descriptions of the herring gull's cognitive programs are entirely in terms of the functional relationship among different pieces of information; they describe two simple information-processing systems. Moreover, precise descriptions of these cognitive programs can capture the way in which information is used to generate adaptive behavior. Of course, these programs are embodied in the herring gull's neurobiological "hardware." Knowledge of this hardware, however, is not necessary for understanding the programs as information-processing systems. Presumably, one could build a silicon-based robot, using chemical processes completely different from those present in the gull's brain, that would produce the same behavioral output (pecking at red dot) in response to the same informational input (seeing red dot). The robot's cognitive programs would maintain the same functional relationships among pieces of information and would, therefore, be, in an important sense, identical to the cognitive programs of the herring gull. But the physical processes that implement these programs in the robot would be totally different.

Although all information-processing mechanisms operate by virtue of the physical processes that implement them, cognitive descriptions and physicalist ones are not equivalent, but complementary. They cannot be reduced to each other. For this reason, the information-processing descriptions of cognitive science are not merely metaphors in which brains are compared to computers. Their status as an independent level of psychological explanation can be established by considering the fact that the same information-processing relationships can be embodied in many different physical arrangements. The text-editing program Wordstar, for example, can run on machines with many different kinds of physical architectures, but it always has the same functional design at an information-processing level—the same key strokes will move the cursor, delete a word, or move a block of text. And the robot "gull" will still peck at a red dot, even though its programs are embodied in silicon chips rather than in neurons. These relationships can be described independently of their physical instantiation in any particular computer or organism, and can be described with precision. Thus, an information-processing program, whether in an organism or in a computer, is a set of invariant relationships between informational inputs and "behavioral" outputs. Moreover, from the point of view of the adaptive regulation of behavior, it is the cognitive system of relationships that counts. Given that the correct information-processing steps are carried out, selection pressures on psychological mechanisms are "blind" to the specific physical implementation of their information-processing structure (except insofar as different physical implementations may vary in factors such as metabolic cost). Because the primary function of the brain is the adaptive regulation of behavior and physiology in response to information, natural selection retains neural mechanisms on the basis of their ability to create functionally organized relationships between information and behavior (e.g., the sight of a predator activates inference procedures that cause the organism to hide or flee) or between information and physiology (e.g., the sight of a predator increases the organism's heart rate in preparation for flight). The mechanism is selected to create the correct information-behavior or information-physiology relationship and, so long as the physical implementation produces this relationship, its particular form is free to vary according to other factors. Indeed, at certain points in development, injury to the human brain can sometimes be "repaired" in the sense that different neurons re-create the same ordered relationship between information and behavior that the damaged ones had implemented prior to the injury (Flohr, 1988). When "rewiring" of this kind occurs, the information-processing relationship is preserved, not its physical instantiation.

In short, it is primarily the information-processing structure of the human psychological architecture that has been functionally organized by natural selection, and the neurophysiology has been organized insofar as it physically realizes this cognitive organization. Because the function of the brain is informational in nature, its richly organized functional structure is only visible when its properties are described in cognitive terms. Much of great interest can be learned by investigating the brain in neurobiological terms, but its adaptive dimension will remain invisible unless and until its mechanisms are described in a language that is capable of expressing its informational functions.

For these reasons, the invariant functional organization of complex psychological adaptations is more likely to be captured by cognitive descriptions than by neuroscience ones.[4] Just as mathematics is an indispensable language for describing many scientific phenomena, information-processing language is a precise descriptive vehicle for capturing how complex systems functionally interact with complex environments. What mathematics is for physics, cognitive descriptions can be for a science of psychology and behavior.

The use of information-processing language is not enough, however. Alone, it is no more useful for discovering invariances in functional organization than any other descriptive language. Unless one knows what counts as functional, one cannot recognize complex functional design even when one sees its operation. Is friendship functional? Is anger? Is joining a group? Is pregnancy sickness? Unless one knows what adaptive problems a species encountered during its evolutionary history and what would have counted as solutions to these problems, these questions are unanswerable. To discover invariances in the functional organization of the human mind, the language and methods of cognitive science must be used in concert with principles drawn from evolutionary biology.

Where Evolutionary Biology and Cognitive Psychology Meet

Conceptual systems, models, and theories function as organs of perception: They allow new kinds of evidence and new relationships to be perceived (Popper, 1972). As Einstein remarked, "it is the theory which decides what we can observe" (Heisenberg, 1971, p. 63). The tools of evolutionary functional analysis function as an organ of perception, bringing the blurry world of human psychological and behavioral phenomena into sharp focus and allowing one to discern the formerly obscured level of our richly organized species-typical functional architecture.

Theories about selection pressures operating in ancestral environments place important constraints on—and often define—what can count as an adaptive function. Indeed, many theories of adaptive function define what would count as adaptive *information-processing.* Consider, for example, Hamilton's rule, which describes the selection pressures operating on mechanisms that generate behaviors that have a reproductive impact on an organism and its kin (Hamilton, 1964). The rule defines (in part) what counts as biologically successful outcomes in these kinds of situations. These outcomes often cannot be reached unless specific information is obtained and processed by the organism.

In the simplest case of two individuals, a mechanism that produces acts of assistance has an evolutionary advantage over alternative mechanisms if it reliably causes individual i to help relative j whenever $C_i < r_{i,j}B_j$. In this equation, C_i = cost to i of rendering an act of assistance to j, measured in terms of foregone reproduction, B_j = benefit to j of receiving that act of assistance, measured in terms of enhanced reproduction, and $r_{i,j}$ = the probability that a randomly sampled gene will be present at the same locus in the relative due to joint inheritance from a common ancestor.

Other things being equal, the more closely psychological mechanisms reliably produce behavior that conforms to Hamilton's rule, the more strongly they will be selected for. Under many ecological conditions, this selection pressure defines an information-processing problem that organisms will be selected to evolve mechanisms to solve.

Using this description of an adaptive problem as a starting point, one can immediately begin to define the cognitive subtasks that would have to be addressed by any set of mechanisms capable of producing behavior that conforms to this rule. What information-processing mechanisms evolved to reliably identify relatives, for example? What criteria and procedures do they embody—for example, do these mechanisms define an individual as a sibling if that individual was nursed by the same female who nursed you? What kind of information is processed to estimate $r_{i,j}$, the degree of relatedness? Under ancestral conditions, did siblings and cousins co-reside, such that one might expect the evolution of mechanisms that discriminate between the two? After all, $r_{i,full\ sib} = 4r_{i,\ first\ cousin}$. What kind of mechanisms would be capable of estimating the magnitudes of the consequences of specific actions on one's own and on others' reproduction? How are these various pieces of information combined to produce behavior that conforms to Hamilton's rule? And so on.

This example highlights several points. First and most important, it shows how knowledge drawn from evolutionary biology can be used to discover functional organization in our psychological architecture that was previously unknown. Hamilton's rule is not intuitively obvious; no one would look for psychological mechanisms that are well-designed for producing behavior that conforms to this rule unless they had already heard of it. After Hamilton's rule had been formulated, behavioral ecologists began to discover psychological mechanisms that embodied it in nonhuman animals (Krebs & Davies, 1984). Unguided empiricism is unlikely to uncover a mechanism that is well-designed to solve this kind of problem.

Second, this example illustrates that one can easily use the definition of an adaptive problem to generate hypotheses about the design features of information-processing mechanisms, even when these mechanisms are designed to produce social behavior. It allows one to break the adaptive problem down into cognitive subtasks, such as kin recognition and cost/benefit estimation, in the same way that knowing that the adaptive function of the visual system is scene analysis allows one to identify subtasks such as depth perception and color constancy.

Third, the example shows how knowing the ancestral conditions under which a species evolved can suggest hypotheses about design features of the cognitive adaptations that solve the problem. For example, co-residence is a reliable cue of sib-hood in some species, but other cues would have to be picked up and processed in a species in which siblings and cousins co-reside.

Fourth, Hamilton's rule provides one with a standard of good design for this particular problem. Such standards are an essential tool for cognitive scientists because they allow them to identify whether a hypothesized mechanism is capable of solving the adaptive problem in question and to decide whether that mechanism would do a better job under ancestral conditions than alternative designs. This allows one to apply the powerful methods of learnability analysis outside of psycholinguistics, to adaptive problems involving social behavior (see pp. 73–77, on evolutionary functional analysis).

Fifth, this example illustrates how insights from evolutionary biology can bring functional organization into clear focus at the cognitive level, but not at the neurobiological level. Hamilton's rule immediately suggests hypotheses about the functional organization of mechanisms described in information-processing terms, but it tells one very little about the neurobiology that implements these mechanisms—it cannot be straightforwardly related to hypotheses about brain chemistry or neuroanatomy. Once one knows the properties of the cognitive mechanisms that solve this adaptive problem, however, it should be far easier to discover the structure of the neural mechanisms that implement them.

The intellectual payoff of coupling theories of adaptive function to the methods and descriptive language of cognitive science is potentially enormous. By homing in on the right categories—ultimately adaptationist categories—an immensely intricate, functionally organized, species-typical architecture can appear, with perhaps some additional thin films of frequency-dependent or population-specific design as well (e.g., McCracken, 1971). Just as one can now flip open *Gray's Anatomy* to any page and find an intricately detailed depiction of some part of our evolved species-typical morphology, we anticipate that in 50 or 100 years one will be able to pick up an equivalent reference work for psychology and find in it detailed information-processing descriptions of the multitude of evolved species-typical adaptations of the human mind, including how they are mapped onto the corresponding neuroanatomy and how they are constructed by developmental programs.

The Impact of Recurrent Environmental and Organismic Structure on the Design of Adaptations

Organisms transact the business of propagation in specific environments, and the persistent characteristics of those environments determine the dangers, opportunities, and elements the organism has to use and to cope with in its process of propagation. Consequently, the structure of the environment causes corresponding adaptive organization to accumulate in the design of the organism (Shepard, 1987a; Tooby & Cosmides, 1990b). For example, the design of eyes reflects the properties of light, objects, and surfaces; the design of milk reflects the dietary requirements of infants (and what was dietarily available to mothers); the design of claws reflects things such as the properties of prey animals, the strength of predator limbs, and the task of capture and dismemberment. This functional organization in the organism—its set of adaptations—is designed to exploit the enduring properties of the environment in which it evolved (termed its environment of evolutionary adaptedness, or EEA) and to solve the recurring problems posed by that environment. Adaptations evolve so that they mesh with the recurring structural features of the environment in such a way that reproduction is promoted in the organism or its kin. Like a key in a lock, adaptations and particular features of the world fit together tightly, to promote functional ends.

Moreover, from the point of view of any specific design feature or adaptation, the rest of the encompassing organism itself constitutes an enduring environmental structure as well. New adaptations or design features will be selected for on the basis of how well they productively coordinate with the persistent characteristics of this internal environment, as well as with the external environment. This is why adaptations evolve to fit together with each other within the organism so well. Thus, the adaptive mesh between tendon, muscle, and bone is no different in principle than the adaptive mesh between foraging mechanisms and the ecological distribution of food and cues reliably correlated with its presence (Real, 1991). Obviously, therefore, adaptations may solve endogenous adaptive problems and may improve over evolutionary time without necessarily being driven by or connected to any change in the external environment.

Long-term, across-generation recurrence of conditions—external, internal, or their interaction—is central to the evolution of adaptations, and it is easy to see why. Transient conditions that disappear after a single or a few generations may lead to some temporary change in the frequency of designs, but the associated selection pressures will disappear or reverse as often as conditions do. Therefore, it is only those conditions that recur, statistically accumulating across many generations, that lead to the construction of complex adaptations. As a corollary, anything that is recurrently true (as a net statistical or structural matter) across large numbers of generations could potentially come to be exploited by an evolving adaptation to solve a problem or to improve performance. For this reason, a major part of adaptationist analysis involves sifting for these environmental or organismic regularities or invariances. For example, mental states, such as behavioral intentions and emotions, cannot be directly observed. But if there is a reliable correlation over evolutionary time between the movement of human facial muscles and emotional state or behavioral intentions, then specialized mechanisms can evolve that infer a person's mental state from the movement of that person's facial muscles (Ekman, 1973, 1984; Fridlund, in press). Indeed, evidence drawn from cognitive neuroscience indicates that we do have mechanisms specialized for "reading" facial expressions of emotion (Etcoff, 1983, 1986).

To begin with, a cognitive adaptation can, through exploiting the world's subtle statistical structure, go far beyond the information it is given, and reconstruct from fragmentary cues highly accurate models of local conditions by exploiting these relationships (e.g., self-propelled motion is correlated with the presence of an animal; a sharp discontinuity in reflected light intensity is correlated with the presence of an edge). This evolutionary Kantian position has already been richly vindicated in the fields of perception and psychophysics (see, e.g., Marr, 1982; Shepard, 1981, 1984, 1987a, this volume), where the representations that our evolved computational systems construct go far beyond what is "logically" warranted solely by the sensory information itself, usually settling on single preferred interpretations. Our minds can do this reliably and validly because this fragmentary information is operated on by evolved procedures that were selected precisely because they reflect the subtle relationships enduringly present in the world (e.g., shading cues that are correlated with shape and depth, time-location relationships that are correlated with the most probable kinematic trajectories followed by natural objects). These mechanisms supply a privileged organization to the available sense data so that the interaction of the two generates interpretations that usually correspond to actual conditions in the external world. In the absence of specialized mechanisms that assume and rely on certain relationships being characteristic of the world, recovering accurate models of the external world from sense data would be an insoluble computational problem (Marr, 1982; Poggio et al., 1985).

Parallel ideas form the centerpiece of Chomskyan psycholinguistics: Children must be equipped with specialized mechanisms ("mental organs") that are functionally organized to exploit certain grammatical universals of human language. Otherwise, language learning would be an unsolvable computational problem for the child (Chomsky 1957, 1959, 1975, 1980; Pinker 1979, 1982, 1984, 1989; Wexler & Culicover, 1980). The discovery and exploratory description of such universal subtle relationships present in the "world" of human language is a primary activity of modern linguists and psycholinguists. Proposed mechanisms for language learning that do not include specialized procedures that exploit these relationships have been repeatedly shown to be inadequate (e.g., Pinker 1989, 1991; Pinker & Prince, 1988). As in perception, adaptations for grammar acquisition must mesh with the enduring structure of the world. But in this case, the recurrent structure to be meshed with is created by the species-typical design of other (adult) human minds, which produce grammars that manifest certain relationships and not others.

Due to common evolutionary ancestry, the living world of plants and animals is structured into species and other more inclusive units that share large sets of properties in common: Wolves resemble other wolves, mammals other mammals, and so on. Living things occur in so-called natural kinds. This is another enduring set of relationships in the world that our minds evolved to exploit. Ethnobiologists and cognitive anthropologists such as Atran and Berlin have shown that the principles humans spontaneously use in categorizing plants and animals reflect certain aspects of this enduring structure, and are the same cross-culturally as well (Atran, 1990; Berlin, Breedlove, & Raven, 1973).

In the last decade, the field of cognitive development has been revolutionized by the discovery that the principles of inference that infants and children bring to the tasks of learning are organized to reflect the particular recurrent structure of specific problem domains, such as object construal and motion, the differences between artifacts and living kinds, physical causality, and so on (see, e.g., Carey & Gelman, 1991). These evolved, domain-specific cognitive specializations have been shown to be specialized according to topic and to develop in the absence of explicit instruction.

For example, contrary to the Piagetian notion that infants must "learn" the object concept, recent research has shown that (at least) as early as 10 weeks—an age at which the visual system has only just matured—infants already have a sensorily-integrated concept of objects as entities that are continuous in space and time, solid (two objects cannot occupy the same place at the same time), rigid, bounded, cohesive, and move as a unit (e.g., Spelke, 1988, 1990, 1991). Indeed, when infants of this age are shown trick displays that violate any of these assumptions, they indicate surprise—one could almost say in such cases that the object concept embodied in their evolved mechanisms causes them to "disbelieve" the evidence of their senses (Leslie, 1988). By 27 weeks, infants already analyze the motion of inanimate objects into submovements and use this parsing to distinguish causal from noncausal relationships (Leslie, 1988; Leslie & Keeble, 1987). Needless to say, these are all relationships that accurately reflect the evolutionarily long-enduring structure of the world.

A. Brown (1990) has shown that early causal principles such as "no action at a distance" guide learning about tool use in children as young as 18 months; these children categorize tools for use according to functional properties (e.g., has a hooked end for pulling) over nonfunctional properties (e.g., color). In contrast, the same children have great difficulty learning how to use a tool when its mechanism of action appears to violate one of their concepts about physical causality—concepts that mirror certain aspects of Newtonian mechanics.

Very young children also make sharp distinctions between the animate and inanimate worlds. Throughout our evolutionary history, being an animal has been reliably—if imperfectly—correlated with self-generated motion, whereas inanimate objects rarely move unless acted upon by an outside force. Recent research suggests that young children use this cue to distinguish the animate from the inanimate worlds, and make very different inferences about the two (Gelman, 1990b; Premack, 1990). More generally, experiments by Keil (1989) and others indicate that the kind of inferences children spontaneously make about "natural kinds," such as animals, plants, and substances, differ sharply from those they are willing to make about human-made artifacts. Natural kinds are viewed as having invisible "essences" that bear a causal relation to their perceptual attributes, whereas artifacts are defined by how their perceptual attributes subserve their (intended) function. In an important series of experiments, Gelman and Markman (1986, 1987; Markman, 1989) found that natural kinds were a powerful organizer of inference in young children. In general, being a member of a natural kind carries more inferential weight than being perceptually similar. In addition, children give more weight to natural kind membership when reasoning about traits that actually *are* more likely to vary as a function of membership in a natural kind, such as breathing, than when reasoning about traits that are more likely to vary as a function of perceptual similarity, such as weight or visibility at night (for summary, see Markman, 1989).

These principles apply far beyond these few simple cases. The world is full of long-enduring structure, and the mind appears to be full of corresponding mechanisms that use these structural features to solve a diverse array of adaptive problems: geometrical and physical relationships that shape the probability of various trajectories (Shepard, 1984), biomechanically possible and impossible motions (Shiffrar & Freyd, 1990), momentum effects on trajectories (Freyd, 1987), correlations between the ingestion of plant toxins and teratogenesis (Profet, 1988, this volume), privileged relationships between the gravitational field and the orientation of objects in the world (Triesman, 1977), and on and on. It is only for expository convenience that we have mostly focused on mechanisms bearing on categorization and inference ("knowledge"), rather than on motivation, emotion, and decision making ("value"). The structure of the world is reflected in the nature of behavior-regulating systems as well because the long-term statistical structure of the world systematically creates relationships between choices and adaptive consequences. (For a discussion of how emotional adaptations reflect the relationship between decisions and the detailed structure of ancestral conditions, see Tooby & Cosmides, 1990b.) Mind/world relationships extend all the way from the ease with which people acquire fears of spiders and snakes (Marks, 1987; Seligman, 1971), to the more subtle impact that aesthetic factors have on habitat choice and wayfinding (Kaplan, this volume; Orians & Heerwagen, this volume), to the relative unwillingness of adults to have sex with people with whom they co-resided for long periods during childhood (McCabe, 1983; Parker & Parker, 1986; Pastner, 1986; Shepher, 1983; Westermarck, 1891; Wolf, 1966, 1968; Wolf & Huang, 1980; N. W. Thornhill, 1991), to the intensity with which parents and children may come to love each other (Bowlby, 1969), to the often violent passions humans exhibit when they discover the existence of spousal infidelity (Daly & Wilson, 1988; Wilson & Daly, this volume).

For those who study psychological adaptations, the long-enduring structure of the world provides a deeply illuminating source of knowledge about the evolved architecture of the mind. As Shepard has so eloquently put it, there has been the evolution of a mesh between the principles of the mind and the regularities of the world, such that our minds reflect many properties of the world (Shepard, 1987a). Many statistical and structural relationships that endured across human evolution were "detected" by natural selection, which designed corresponding computational machinery that is specialized to use these regularities to generate knowledge and decisions that would have been adaptive in the EEA. Because the enduring structure of ancestral environments *caused* the design of psychological adaptations, the careful empirical investigation of the structure of environments, from a perspective that focuses on adaptive problems and outcomes, can provide powerful guidance in the exploration of the mind. The long-term structure of the ancestral world is worth knowing, worth studying, and worth relating to psychology. This realization vastly widens the scope of information that can be brought to bear on questions in psychology: Evolutionary biology, paleoanthropology, hunter-gatherer studies, behavioral ecology, botany, medicine, nutrition, and many other fields can be mined for information that suggests specific hypotheses, guides one toward productive experimentation, and informs one about the broad array of functionally specialized mechanisms that are likely to be present. The stuff of the mind is the stuff of the world, and so the investigation of the rich structure of the world provides a clearly observable and empirically tractable—if not royal—road into the hidden countries of the mind.

THE CENTRAL ELEMENTS OF EVOLUTIONARY FUNCTIONAL ANALYSIS

Approaching the coordination between the structure of the ancestral world and the design features of adaptations with an engineering sensibility is what gives empirical specificity and inferential power to evolutionary functional analysis. The following are five structured components that can be fit together in such an analysis.

1. *An adaptive target*: a description of what counts as a biologically successful outcome in a given situation. Out of the infinite set of potential behavioral sequences, which small subset would count as a solution to the adaptive problem? Here, one wants to know which behavioral outcomes will have the property of enhancing the propagation of the psychological designs that gave rise to them. For example, out of all the substances in the world, which should the organism eat and which should it avoid? With whom should the organism mate? How much parental care should it devote to each offspring? When should the organism join a coalition? What inferences should be drawn on the basis of the retinal display about the location of various surfaces? In defining an adaptive target, the goal is to ascertain whether the proposed behavioral outcome, in combination with all the other activities and outcomes produced by the organism, will enhance design propagation under ancestral conditions.

2. *Background conditions*: a description of the recurrent structure of the ancestral world that is relevant to the adaptive problem. One wants to know what features of the ancestral world were sufficiently stable to support the evolution of a design that could produce an adaptive target. This could be a part of the external environment, another part of the standard design of the organism, or a combination of the two. This includes the information available to solve the problem, the environmental and endogenous obstacles to solving the problem, and so on. So, for example, the regular spatial orientation of human eyes with respect to each other, the face, and the ground constitute background conditions for the evolution of face recognition mechanisms in infants. Often, but not always, the ancestral world will be similar to the modern world (e.g., the properties of light and the laws of optics have not changed). However, one needs to know something about hunter-gatherer studies and paleoanthropology to know when ancestral conditions germane to the adaptive problem diverge from modern conditions. Of course, when there is a difference between the two, ancestral conditions are the applicable ones for the purpose of analyzing the functional design of an adaptation because they are the cause of that design. Modern environments are relevant to the analysis of the ontogeny of mechanisms and their calibration. It is important to keep in mind that a mechanism that was capable of producing an adaptive target under ancestral conditions may not be capable of doing so under modern ones. Our visual system fails to maintain color constancy under sodium vapor lamps in modern parking lots (Shepard, this volume), and attempting to understand color constancy mechanisms under such unnatural illumination would have been a major impediment to progress.

3. *A design*: a description of the articulated organization of recurrent features in the organism that together comprise the adaptation or suspected adaptation. A design

description of the eye, for example, would include a specification of its species-typical parts and the manner in which they interact to produce an adaptive target.

The design—or even the existence—of a proposed information-processing mechanism is frequently unknown. Indeed, an appropriate functional description of a design is often what one is trying to discover. When this is the case, this step in an evolutionary functional analysis would be the construction of a hypothesis about the existence and design features of a psychological adaptation. This might include what environmental cues the mechanism monitors, what information it draws from other mechanisms, how it categorizes and represents this information, what procedures or decision rules transform the informational input, what kinds of representations or behaviors it produces as output, which mechanisms use its output for further processing, how its output is used by other mechanisms to generate behavior, and so on. The more causally explicit one can make the design description at the cognitive level, the better. Eventually, one hopes to have a description of the neurobiological implementation of the adaptation as well.

4. *A performance examination*: a description of what happens when the proposed adaptation mechanistically interacts with the world. What range of outcomes does the design actually produce? Like putting a new aircraft prototype in a wind tunnel, what one is looking for is a good causal or "engineering" analysis of how the proposed design actually performs under conditions that are representative of situations our ancestors routinely faced, and how it performs under present conditions as well. For a proposed language acquisition device, for example, one wants to model how its information-processing procedures perform when they encounter normal linguistic environments, in order to see whether the interaction of procedures and environment assembles an increasingly elaborated computational system capable of producing intelligible and grammatical sentences. Similarly, one wants to model how psychological mechanisms in women or men interact with their social and informational environments to produce mating preferences. We want to emphasize that we are looking here for a mechanistic or causal description of how the system generates output given input. Statements like, "the human child learns its culture through imitation and generalization" are not models of how input generates output. They are too unspecified to qualify as hypotheses or explanations; we should have ceased treating them as such a long time ago.

5. *A performance evaluation*: a description or analysis of how well (or how poorly) the design, under circumstances paralleling ancestral conditions, managed to produce the adaptive target (the set of biologically successful outcomes). The better the mechanism performs, the more likely it is that one has identified an adaptation.

It is just as important, however, to see whether the proposed mechanism produces the behaviors one actually observes from real organisms under modern conditions. If it does, this suggests that the researcher is converging on a correct description of the design of the mechanisms involved, whether they are producing behavior that is currently adaptive or not. The Westermarck incest avoidance mechanism, for example, passes both tests. It produces adaptive outcomes under ancestral (and many modern) conditions (e.g., distaste for sex between siblings who co-resided as children), and it also explains the nonadaptive outcomes that are observed under certain modern conditions (e.g., distaste for sex between kibbutz crèche mates who co-resided as children [Shepher, 1983]; distaste for sex with spouses who were adopted into one's family at a young age and with whom one was raised [Wolf & Huang, 1980]).

In short, an evolutionary functional analysis consists of asking a series of engineering questions: Would the proposed design have interacted with properties of the ancestral world to produce target adaptive outcomes? Does the proposed design interact with properties of the modern world to produce outcomes that one actually observes in real organisms, whether these outcomes are adaptive or not? Is there an alternative design that is better able to generate adaptive targets under ancestral conditions? If so, then are there any background conditions that one has overlooked that would have prevented the alternative design from evolving? And so on.

Natural selection is the process that shapes biological form to match function, and this link between form and function has been a critically illuminating relationship in thousands of applications. Ever since Harvey's question about why there were valves in the veins led him to discover the circulation of the blood, functional questions about organismic design have been a powerful engine for the discovery of new knowledge (Mayr, 1983). Those even distantly connected to organismic biology have become aware of the spectacular functionalist revolution that has transformed the field over the last 30 years, placing adaptationism on a new and far more rigorous foundation (Hamilton, 1964; Maynard Smith, 1982; see, especially, Williams, 1966). The reason why Lewontin and Gould's accusation (famous among social scientists) that adaptationism consists of post hoc storytelling has so resoundingly failed to impress practicing evolutionary biologists is that they saw on a daily basis that adaptationism was anything but post hoc (Gould & Lewontin, 1979; for discussion, see Pinker & Bloom, this volume). Simply put, an explanation for a fact by a theory cannot be post hoc if the fact was unknown until after it was predicted by the theory and if the reason the fact is known at all is because of the theory. Functionalist analysis in biology has motivated thousands of predictions about new and critical phenomena, whose subsequent discovery confirmed the productivity of the emerging paradigm. Lewontin and Gould's critique has primarily impressed those outside of evolutionary and organismic biology who have not been exposed on a professional basis to the flood of new findings that were both generated and economically organized by the newly emerging functionalist principles.

When they are linked together, the five components outlined above not only provide a framework for the explanation of facts that are already known; they also form a powerful heuristic system for the generation of new knowledge. Depending on which questions you need answered and what information you already have, you can put these relationships to a number of richly productive alternative uses. For example, if you are trying to discover the structure of unknown psychological mechanisms, you first need to integrate steps 1 and 2 together into a definition of an adaptive problem (what Marr called a computational theory or task analysis; Marr, 1982). You need to determine things such as what information was routinely available in the environment and in the organism to solve the problem (step 2), and what outcomes constituted a successful solution to the problem (step 1). From this, you can begin to develop hypotheses about the nature of the information-processing mechanisms that might have evolved to solve the problem, and then empirically test for their presence. (For a discussion of this approach, see Marr, 1982, and Cosmides & Tooby, 1987. For some applications of this approach to specific psychological problems: on vision, see Marr, 1982; on mechanisms specialized for reasoning about social exchange, see Cosmides, 1989, Cosmides & Tooby, 1989, this volume, and Gigerenzer & Hug, in press; on mechanisms regulating parental solicitude, see Mann, this volume, and Daly & Wilson, 1988). In short, by using steps 1 and 2, one can create a hypothesis about function that leads to the discovery of form. This use of the elements of evolutionary functional analysis guides the researcher step by step from a definition of an adaptive problem to the discovery and mapping of the mechanisms that solve it.

An alternative starting point is step 3: a well-specified candidate hypothesis about the structure of an information-processing mechanism. So, for example, you might hypothesize that operant conditioning explains the acquisition of natural language grammars. To proceed with an evolutionary functional analysis, you would then need to develop a description of the relevant environmental features (step 2) and define what counts as a successful outcome (step 1). You would then proceed to steps 4 and 5—performance examination and evaluation. If your hypothesis about design is correct, then the step 4 performance examination will reveal that the design's interaction with the relevant environment features is at least *capable* of producing a successful outcome. The performance evaluation of step 5 will allow you to determine whether the design hypothesized in step 3 is better at producing adaptive outcomes than alternative designs.

We will refer to the application of steps 4 and 5 as the *solvability criterion*: To be correct, a cognitive adaptation must be capable of solving the proposed problem or generating behavior that we know humans routinely perform and of doing so given the relevant background conditions. Although this may seem like an obvious step, theories in psychology are rarely evaluated in this way, which has allowed entire research communities to labor under the impression that, say, associationism or imitation constitute effective explanations of the phenomena they studied. Such tests of computational performance—or *learnability analyses* as they are called when applied to learning tasks—were pioneered in psycholinguistics by Pinker and colleagues (1979, 1984, 1989, 1991; Pinker & Prince, 1988; Wexler & Culicover, 1980) in order to evaluate which theories of language acquisition could actually account for the fact that children learn the language of their local community. By using this method one can, in fact, rule out entire classes of theories as inadequate, without having to empirically test each one of an inexhaustible set of trivial variants. Because there are an infinite number of alternative theories, empirical falsification is not by itself a practical research strategy; it must be combined with other sources of valid inference if one is to be able to draw larger and more interesting conclusions. For psychologists, the analysis of computational performance is one way of doing this.

Yet another approach to evolutionary functional analysis begins with noting the existence of a complexly articulated and recurrent phenotypic pattern—for example, eyes, teeth, pregnancy sickness, or sexual jealousy—and investigating whether it might be the expression of an adaptation (Williams, 1966, p. 10). In such cases, one is following the logic in yet another direction: Given a known phenotypic structure (step 3), one dissects the environment (step 2) and the requirements for reproduction (step 1), to find out whether they compose a well-defined adaptive problem for which the reliable outcomes of the design (step 4) constitute a well-engineered solution (step 5). Profet's proposal that pregnancy sickness constitutes an adaptation to limit maternal ingestion of teratogens during the most vulnerable phases of embryogenesis is an excellent application of this approach (Profet, this volume). It should be stressed that this is the only type of functionalist analysis to which Gould and Lewontin's accusation of post hoc storytelling could possibly apply, even in principle, since it is the only one that works backward from known facts about phenotypic design. Yet, even here, the critique could only apply if all facts about the environment, the other parts of the organism, and the structure believed to be an adaptation were known in advance. In practice, this is never the case. This form-to-function approach is just as productive as the others because it leads to the prediction and organization of previously unknown facts, usually about additional design features of the organism as well as about the recurrent structure of the world. For example, the study of the visual system has profited immensely from the fact that scientists knew that the eye exists and that the visual system's function is to perform scene analysis given data transduced by the eye. Indeed, the functionalist approach to the study of vision has generated one of the most sophisticated and least ad hoc bodies of knowledge in psychology. As Mayr put it, summarizing the historical record in response to accusations that adaptationist research was simply post hoc storytelling, "The adaptationist question, 'What is the function of a given structure or organ?' has been for centuries the basis for every advance in physiology" (1983, p. 32). Adaptationist principles can provide equally powerful guidance for research in psychology as well.

Even if every aspect of a mechanism were already known, examining the detailed transactions between selected features of the environment and selected parts of the mechanism would clarify many features of its functional organization, such as which aspects of the design perform the work (e.g., which aspects of pregnancy sickness cause the mother to avoid ingesting teratogens) and which are functionless or even harmful side effects (such as calorie reduction during the first trimester). Naturally, the form-to-function approach does include the risk of answering the post hoc "why" question that Gould and Lewontin so disdain; that is, of explaining why already known features of biological designs came to be as they are. But even physics and geology run the "risk" of addressing such Kiplingesque post hoc questions as why Mercury has an orbit that deviates from the predictions of Newtonian mechanics, why Asia has the Himalayas, or why the universe has its present set of four interactions, temporal asymmetry, background radiation, and particle distribution. In science, this is usually called "explanation."

TOWARD A POST-STANDARD MODEL VIEW OF DEVELOPMENT

Development from an Adaptationist Perspective

The recognition that organisms are integrated collections of problem-solving mechanisms organized to propagate their designs brings with it an adaptationist framing of development. An adaptation is, by its nature, an improbably good organization of elements and so will not often spontaneously come into existence merely by chance. Instead, for adaptations to exist, they must be specifically constructed from the materials present in evolutionarily normal environments. Accordingly, the developmental programs and machinery responsible for assembling an adaptation correctly are also adaptations. As adaptations, they themselves have complex structures that assume and require recurrent features of the world, and that interact with this recurrent structure to produce biologically functional targeted outcomes.

Hence, the primary function or target of developmental adaptations (which include the genes) is to reconstruct in offspring the evolved functional organization that was present in their parents, which is predominantly species-typical design. The genes and the mechanisms of genetic transmission are, of course, adaptations to the problem of faithfully replicating into the offspring critical information necessary to reconstruct this design. The genes come embedded in a matrix of cellular and developmental machinery constituting an additional set of adaptations that use the genetic structure as regulatory elements to institute and to guide embryogenesis and subsequent development along species-standard pathways. For this reason, it is useful to think of the genes together with the developmental machinery as one integrated suite of adaptations—the developmental programs—and to distinguish the minor idiosyncratic features of an individual's genes and zygotic machinery from the recurrent or species-typical dimensions that have endured long enough to have been organized by natural selection. The latter specify the species-standard physiological and psychological architecture visible in all humans raised in normal environments, whereas the former specify the usually minor perturbations within that architecture (Tooby & Cosmides, 1990a).

Why do we so often connect complex adaptations or evolved architectures with concepts such as *species-typical, human universal, species-standard, recurrent*, and so on? This is because when humans are described from the point of view of their complex adaptations, differences tend to disappear, and a universal architecture stands out in stark relief. This is both empirically the case (nearly everyone has two eyes, two hands, the same sets of organs, and so on) and theoretically expected to be the case if organisms are primarily collections of complex adaptations. The logic is straightforward (Tooby & Cosmides, 1990a; see also Tooby, 1982):

1. A species is a group of organisms with a common history of interbreeding and a continuing ability to interbreed to form offspring who can typically reproduce at least as well as their parents.
2. To survive and reproduce in a complex world, organisms need complex problem-solving machinery (complex adaptations).
3. Complex adaptations are intricate machines that require complex "blueprints" at the genetic level. This means that they require coordinated gene expression, involving hundreds or thousands of genes to regulate their development.
4. Sexual reproduction automatically breaks apart existing sets of genes and randomly generates in the offspring new, never before existing combinations of genes at those loci that vary from individual to individual.
5. If genes differed from individual to individual in ways that significantly impacted the developed design of the component parts of complex adaptations, then existing genetic combinations whose developed expressions had fit together into complex adaptations would be pulled apart by sexual recombination. Equally, new combinations would be thrown randomly together, resulting in phenotypes whose parts were functionally incompatible. This is because parts in any complex machine are functionally interdependent: If you tried to build a new car engine out of a mixture of parts from a Honda and a Toyota, the parts would not fit together. To build a new engine whose component parts fit together, you would have to salvage parts from two "parents" that were of the same make and model.
6. Because sexual recombination is a random process, it is improbable that all of the genes necessary for a complex adaptation would be together in the same individual if the genes coding for the components of complex adaptations varied substantially between individuals.
7. Therefore, it follows that humans, and other complex, long-lived, outbreeding organisms, must be very nearly uniform in those genes that underlie our complex adaptations.
8. By the same token, sexually reproducing populations of organisms freely tolerate genetic variation to the extent that this variation does not impact the complex adaptive organization shared across individuals. To return to our car engine example, the color of the parts is functionally irrelevant to the operation of the car and so can vary arbitrarily and superficially among cars of the same make and model; but the shapes of the parts are critical to functional performance and so cannot vary if the "offspring" design is to function successfully.

These constraints on variation apply with equal force to psychological adaptations: Even relatively simple cognitive programs, "mental organs," or neurological structures must contain a large number of interdependent processing steps, limiting the nature of the variation that can exist without violating the functional integrity of the psychological adaptation. The psychic unity of humankind—that is, a universal and uniform human nature—is necessarily imposed to the extent and along those dimensions that our psychologies are collections of complex adaptations. Therefore, it is *selection* interacting with sexual recombination that tends to impose near uniformity at the functional level in complex adaptive designs (as well as in whatever is developmentally coupled to complex functional structure). It is selection that is responsible for what we have been calling our universal evolved psychological and physiological architecture.

There is no small irony in the fact that Standard Social Science Model hostility to adaptationist approaches is often justified through the accusation that adaptationist approaches purportedly attribute important differences between individuals, races, and classes to genetic differences. In actuality, adaptationist approaches offer the explanation for why the psychic unity of humankind is genuine and not just an ideological fiction; for why it applies in a privileged way to the most significant, global, functional, and complexly organized dimensions of our architecture; and for why the differences among humans that are caused by the genetic variability that geneticists have found are so overwhelmingly peripheralized into architecturally minor and functionally superficial properties. If the anti-adaptationists were correct (e.g., Gould & Lewontin, 1979) and our evolved architectures were not predominantly sets of complex adaptations or properties developmentally coupled to them, then selection would not act to impose cross-individual uniformity, and individuals would be free to vary in important ways and to any degree from other humans due to genetic differences. If the world were, in fact, governed by nonselectionist forces, then the psychic unity of humankind would simply be a fiction.

Modern geneticists, through innovative molecular genetic techniques, have certainly discovered within humans and other species large reservoirs of genetic variability (Hubby & Lewontin, 1966; Lewontin & Hubby, 1966; see reviews in Ayala, 1976, and Nevo, 1978). But it is only an adaptationist analysis that predicts and explains why the impact of this variability is so often limited in its scope to micro-level biochemical variation, instead of introducing substantial individuating design differences. The study of the operation of selection on complex mechanisms makes it difficult to see how more than a tiny fraction of this variation could be constitutive of complex psychological or physiological adaptations.[5]

Thus, human design resolves itself into two primary tiers: First, an encompassing functional superstructure of virtually universal, complexly articulated, adaptively organized developmental, physiological, and psychological mechanisms, resting on a universally shared genetic basis; and, second, low level biochemical variation creating usually slight individuating perturbations in this universal design due to the existence of a reservoir of genetic variability in the species. There may also be some thin films of population-specific or frequency-dependent adaptive variation on this intricate universal structure (see, e.g., Durham, 1991; McCracken, 1971), but for a number of reasons these will be very small in magnitude next to the complex structure of a universal human nature (for discussion, see Tooby & Cosmides, 1990a, 1990b). The primary function of developmental adaptations is to reconstruct in each new individual this complex, functional architecture, and the primary focus of adaptationists is the study of this universal structure.

The fact that humans in ordinary environments reliably develop a clearly recognizable species-typical architecture should in no way be taken to imply that any developed feature of any human is immutable or impervious to modification or elimination by sufficiently ingenious ontogenetic intervention. Nothing about humans could possibly be immune from developmental intervention, simply because we are physical systems open to contact and manipulation by the rest of the world; we are not something made unalterable by inexorable supernatural predestination. People frightened of the myth that biology is destiny can be reassured (just as others may be alarmed) by the fact that there are no limits to what could be done, especially by evolutionarily novel measures: Deliver the right quanta to the right ribosomes or other locations at the right times and anyone or anything could be successively modified into a watermelon or an elephant. In contrast, Standard Social Science Model advocates, such as Gould, tend to equate evolved biological design with immutability without any logical or empirical warrant. As Gould expresses his rather magical belief, "If we are programmed to be what we are, then these traits are ineluctable. We may, at best, channel them, but we cannot change them either by will, education, or culture" (Gould, 1977c, p. 238).

In actuality, the very openness of development to intervention poses a critical set of adaptive problems for developmental adaptations. Their primary function is to successfully reconstruct each functionally necessary detail of our species-typical architecture, including the tens or hundreds of thousands of specific components and arrangements that endow us with a lens, a retina, an optic nerve, language, maternal attachment, emotions, retinotopic maps, ten fingers, a skeleton, color constancy, lungs, a representational system embodying the implicit theory that others have minds, an ability to cooperate, spatial cognition, and so on. Each of these adaptations constitutes a very narrow target of improbably good functional organization. Because the world is full of potential disruptions, there is the perennial threat that the developmental process may be perturbed away from the narrow targets that define mechanistic workability, producing some different and nonfunctional outcome. Developmental adaptations are, therefore, intensely selected to evolve machinery that defends the developmental process against disruption (Waddington, 1962). Profet (this volume) provides an elegant analysis of a psychological adaptation designed to defend against just such threats to adaptive development, protecting embryogenesis from the potentially disruptive plant toxins in the mother's diet through modifying her dietary decisions during pregnancy. More generally, developmental programs are often designed to respond to environmentally or genetically introduced disorder through feedback-driven compensation that redirects development back toward the successful construction of adaptations. Thus, developmental processes have been selected to defend themselves against the ordinary kinds of environmental and genetic variability that were characteristic of the environment of evolutionary adaptedness, although not, of course, against evolutionarily novel or unusual manipulations.

Of course, unlike human-built machines that have a static architecture until they break down, organisms are systematically transformed by developmental adaptations over their life histories from zygote to senescence. Thus, the task facing developmental adaptations is not to assemble a machine of fixed design, but rather to assemble and modify the set of expressed adaptations according to a moving target of age, sex, and circumstance-dependent design specifications. For example, adaptive problems are often specific to a particular life stage, and so the organism must be developmentally timed to have the necessary adaptations for that stage, regardless of whether, as a side effect, they happen to appear before or persist after they are needed (e.g., the placenta, fetal hemoglobin, the sucking reflex, the ability to digest milk, the fear of strangers, ovulation, the ability to be sexually aroused, milk production, and so on).

Hence, the Standard Model assumption—critical to its logic—that the mental organization present in adults but absent from newborns must be "acquired" from the social world has no conceptual foundation and is, in many cases, known to be empirically false. In the worldview of the SSSM, biological construction goes on in the uterus, but at birth the child is "biologically complete" except for growth; at this point, it is surrendered into the sole custody of social forces, which do the remainder of the construction of the individual. This, of course, reflects folk biology, captured in the two dictionary definitions of *innate* as "present from birth" and as "intrinsic." Social constructivist arguments frequently take the form that because thus-and-such is absent at birth, or doesn't appear until after age seven, or until after puberty, it is obviously "learned" or "socially constructed." As a result, a common, but generally irrelevant feature of "nativist" versus "environmentalist" debates is over what is "present from birth." This confuses (among other things) the question of whether something is *expressed* at the time of birth with whether there exists in the individual evolved developmental mechanisms that may activate and organize the expression of an adaptation at some point in the life cycle. Developmental processes continue to bring additional adaptations on line (as well as remove them) at least until adulthood, and there is an increasing amount of evidence to suggest that age-driven adaptive changes in psychological architecture continue throughout adulthood (see, e.g., Daly & Wilson, 1988). Thus, just as teeth and breasts are absent at birth and develop later in an individual's life history, perceptual organization, domain-specific reasoning mechanisms, the language acquisition device, motivational organization, and many other intricate psychological adaptations mature and are elaborated in age-specific fashions that are not simply the product of the accumulation of "experience." Consequently, psychological adaptations may be developmentally timed to appear, disappear, or change operation to mesh with the changing demands of different age-specific tasks, such as parenting, emotional decoding of the mother's voice, language acquisition, species-appropriate song learning, and so on (Daly & Wilson, 1988; Fernald, this volume; Marler, 1991; Newport, 1990).

Equally, although most human psychological and physiological adaptations appear to be sexually monomorphic, some are obviously sexually differentiated to address those adaptive problems whose task demands were recurrently disparate for females and males over evolutionary time (e.g., Buss, 1987, 1989, 1991, this volume; Daly & Wilson, 1988; Ellis, this volume; Silverman & Eals, this volume; Symons, 1979; Wilson & Daly, this volume). For any particular gender difference, many psychologists are interested in whether it was caused (1) by sexually monomorphic psychologies encountering differential treatment by the social world, or (2) by sexually differentiated developmental mechanisms encountering treatment from the social world, whether that treatment was uniform or differential. As interesting as this question may be, however, the fact that an expressed gender difference may first appear after birth, or even late in life, is evidence neither for nor against either of these views.

For these reasons, one needs to distinguish an organism's evolved design or species-typical architecture from its "initial state" (Carey, 1985a); that is, its state at whatever point in development one chooses to define as "initial" (birth, conception, fetus prior to gonadal or neural sexual differentiation, puberty, or whatever). Not all features of evolved human design are or can be present at any one time in any one individual. Thus, the genetically universal may be developmentally expressed as different maturational designs in the infant, the child, the adolescent, and the adult; in females and males; or in individuals who encounter different circumstances. Pregnancy sickness is arguably a feature of our evolved universal design, but it does not appear in males, children, or women who have never become pregnant; it is only present in sexually mature women while they are pregnant. Thus, when we use terms such as "evolved design," "evolved architecture," or even "species-typical," "species-standard," "universal," and "panhuman," we are not making claims about every human phenotype all or even some of the time; instead, we are referring to the existence of evolutionarily organized developmental adaptations, whether they are activated or latent. Adaptations are not necessarily expressed in every individual. They only need to have been expressed often enough in our evolutionary history to have been targets of selection, and, hence, to have been organized by selection so that they reliably develop under appropriate circumstances. For this reason, adaptations and adaptive architecture can be discussed and described at (at least) two levels: (1) the level of reliably achieved and expressed organization (as, for example, in the realized structure of the eye), and (2) at the level of the developmental programs that construct such organization. To avoid cumbersome expressions, we do not usually bother to terminologically distinguish successfully assembled expressed adaptive architecture from the more fundamental developmental adaptations that construct them. Context usually makes obvious which is being discussed.

Selection Regulates How Environments Shape Organisms

Many social and biological scientists have labored under the false impression that only certain things are under the "control," or "influence," or "determination" of the genes or of biology. According to this view, evolutionary approaches are only applicable to those traits under such "genetic control," and the greater the environmental influence

or control, the smaller the domain of things for which evolutionary analyses properly apply (e.g., Sahlins, 1976a; Gould, 1977a, 1977b, 1977c; note, especially, Gould's Standard Model contrast of "genetic control" with the "purely cultural"). In this dualistic conception, the genes are "biological" and evolved, while "the environment"—including the social environment—is nonbiological and nonevolved. In consequence, the environment is held to be something that not only can attenuate, nullify, or even reverse "genetic forces" but may break the causal chain entirely, liberating human affairs from the causal patterning of evolution. For proponents of the SSSM, it is self-evident that the causal forces of evolution and "biology" are located solely inside the organism and are expressed in an unadulterated form only at birth, if then. In contrast, the causal forces of the environment are seen as external to the organism, as having their own independent causal history, and as having no particular reason to act on the organism in such a way as to preserve or elaborate the organism's initial biological organization. In short, the environment is conceptualized as obviously nonbiological in character. Development is consequently portrayed as a process in which the newborn organism—usually seen as a passive clay-like object with some initial biologically given form—is pounded or sculpted by the active and nonbiological environment according to its accidents, structure, or agenda. It follows from this view that biology can only express itself in human life if it is unalterable or at least rigid enough to resist the pounding forces of the environment—a bombardment that begins at birth. One might think of the stubbornly biological aspects of human life as the hardened part of the clay, while the more plastic parts are easily shaped by the environment and quickly lose their initial biological form. Consequently, even if advocates of the SSSM do not want to dichotomize traits cleanly into two sets (e.g., hardened versus wet clay), they could array them by this criterion as more or less biologically determined; that is, as more or less environmentally influenced.

Despite its tenacity in the social sciences at large, this Standard Model view of development has been abandoned by many cognitive scientists and by biologists because it rests on a series of fallacies and misconceptions. To begin with, despite the routine use of such dualistic concepts and terms by large numbers of researchers throughout the social and biological sciences, there is nothing in the real world that actually corresponds to such concepts as "genetic determination" or "environmental determination." There is nothing in the logic of development to justify the idea that traits can be divided into genetically versus environmentally controlled sets or arrayed along a spectrum that reflects the relative influence of genes versus environment. And, most critically, the image of "the environment" as a "nonbiological" causal influence that diminishes the "initial" evolved organization of humans rests on the failure to appreciate the role that the evolutionary process plays in organizing the relationship between our species-universal genetic endowment, our evolved developmental processes, and the recurring features of developmental environments.

In the first place, every feature of every phenotype is fully and equally codetermined by the interaction of the organism's genes (embedded in its initial package of zygotic cellular machinery) and its ontogenetic environments—meaning everything else that impinges on it. By changing either the genes or the environment any outcome can be changed, so the interaction of the two is always part of every complete explanation of any human phenomenon. As with all interactions, the product simply cannot be sensibly analyzed into separate genetically determined and environmentally determined components or degrees of influence. For this reason, *everything*, from the most delicate nuance of Richard Strauss's last performance of Beethoven's Fifth Symphony to the presence of calcium salts in his bones at birth, is totally and to exactly the same extent genetically and environmentally codetermined. "Biology" cannot be segregated off into some traits and not others.

Nevertheless, one could understand and acknowledge that all human phenomena are generated by gene-environment interactions, yet believe that the existence and participation of the environment in such interactions insulates human phenomena from interesting evolutionary patterning. After all, if only our genes evolved, whereas the form of the environment is generated by other processes (such as geology, cultural transmission, epidemiology, and meteorology) then the gene-environment interaction seems to blunt the organizing effects evolution might otherwise have on human life. Although this view seems quite reasonable, a close examination of how natural selection actually adaptively organizes gene-environment interactions over time leads to a very different conclusion, which might be summed up by the counterintuitive claim that "the environment" is just as much the product of evolution as are the genes.

To understand why this is so, one needs to distinguish "the environment" in the sense of the real total state of the entire universe—which, of course, is not caused by the genes or the developmental mechanisms of any individual—from "the environment" in the sense of those particular aspects of the world that are rendered developmentally relevant by the evolved design of an organism's developmental adaptations. It is this *developmentally relevant environment*—the environment as interacted with by the organism—that, in a meaningful sense, can be said to be the product of evolution, evolving in tandem with the organism's organized response to it. The confusion of these two quite distinct senses of "environment" has obscured the fact that the recurrent organization of the environment contributes a biological inheritance parallel to that of the genes, which acts co-equally with them to evolutionarily organize the organism throughout its life.

The assumption that only the genes are evolved reflects a widespread misconception about the way natural selection acts. Genes are the so-called units of selection, which are inherited, selected, or eliminated, and so they are indeed something that evolves. But every time one gene is selected over another, one design for a developmental program is selected over another as well; by virtue of its structure, this developmental program interacts with some aspects of the environment rather than others, rendering certain environmental features causally relevant to development. So, step by step, as natural selection constructs the species' gene set (chosen from the available mutations), it constructs in tandem the species' developmentally relevant environment (selected from the set of all properties of the world). Thus, *both the genes and the developmentally relevant environment are the product of evolution.*

Even more crucially, by selecting one developmental program over another, the evolutionary process is also selecting the mechanisms that determine how the organism will respond to environmental input, including environmental input that varies. A developmental mechanism, by virtue of its physical design, embodies a specification for how each possible state of the developmental environment is to be responded to, if encountered. This is a central but little understood point: There is nothing "in" the environment that by itself organizes or explains the development, psychology, morphology, or behavior of any organism. "The" environment affects different organisms in different ways. We find the smell of dung repellent; dung flies are attracted to it. Temperature at incubation determines the sex of an alligator, but not of a human (Bull, 1983). A honeybee larva that is fed Royal Jelly will become a queen bee rather than a sterile worker, but Royal Jelly will not have this effect on a human baby. Many bats navigate by sound echoes that humans cannot even hear. Rats have an elaborate sense of smell, which their food choice mechanisms use, but their navigation mechanisms ignore smell cues entirely in favor of geometric cues (Gallistel, 1990). Indeed, this last example shows that the developmentally relevant environment is not just organism-specific, it is mechanism-specific. In other words, the actual relationship between environmental conditions and developmental outcomes *is created by the design of the developmental procedures that exist in the organism* and, within the limit of the physically possible, mechanisms could be designed into the system to create a causal relationship between any imaginable environmental input and any imaginable output. In principle, genetic engineers could build honeybee larvae that develop into workers if, and only if, they are exposed to recitations of Allen Ginsberg's "Howl."

Aside from physical necessity, then, it is the evolved design of the organism that decides what organized consequences the environment can have on it. The rules that govern how environments impact the developing organism have themselves evolved and have been shaped by selection. Consequently, the evolutionary process determines how the environment shapes the organism. Over evolutionary time, genetic variation in developmental programs (with selective retention of advantageous variants), explores sampled properties out of the total environment potentially available to be interacted with. This process discovers which recurrent features are useful in the task of organizing and calibrating psychological adaptations and which recurrent features are unreliable or disruptive. It renders the latter irrelevant to development.

A natural response is to claim that although the genes are highly stable, replicated with few mutations from generation to generation, the environment is volatile, rendering any developmental process coordinating the two ineffectual. Once again, however, our intuitions are not a privileged perspective from which one can declare the world to be either stable or variable. Whether the world is "stable" or "variable" depends on the categorization system used or, to put it another way, on which parts of the world are selected to be processed by a mechanism.

Consider, for example, the following thought experiment. Imagine that an identical pool shot is set up every generation on a rather odd pool table. Three of the four cushions wobble continuously and unpredictably, but one happens to be stable. The "genes" determine the exact direction the cue ball is hit each time, while the "environment" (i.e., the angle of the cushions when struck) determines how the shot will be reflected back. Whether a particular shot successfully sinks the target ball in a pocket (i.e., whether it achieves the adaptive target) is determined by the interaction of the direction of the shot and the orientation of the cushion at the time the ball hits it (i.e., the interaction of genes and environment determine the outcome). Assume also that there is variation in the direction of the shot (i.e., in the "genes") and that successful shots cause genes to be retained.

Over the long run, feedback-driven selection will come to determine which direction the ball is hit. In determining this direction, it will also end up selecting the stable cushion for the bank shot, and not the wildly oscillating ones. It will end up directing the shot at exactly that spot along the stable cushion from which the shots are stably successful.

Similarly, selection will design developmental adaptations that respond to those aspects of the world that have a relatively stable recurrent structure, such that the mesh between the two will reliably produce design-propagating outcomes. Just as selection has acted on genetic systems to keep mutations to tolerable levels, selection has acted to "choose" the more stable parts of the environment to render developmentally relevant, such that these aspects of the environment stably mesh with developmental programs to produce reliably developing adaptive architectures.

The Standard Model framing says that the world pre-exists and is not caused by the organism, so that the world's effect on the organism will have no particular tendency to organize the developing organism according to any evolved or adaptive pattern. Equally, the pool-table cushion pre-existed each shot and was not created by them, and the laws of physics determined how each shot would be reflected back. So, in a static SSSM analysis, it is self-evident that the outcome is the mixture of two factors, one "biological" and one "nonbiological," with the nonbiological diluting, obliterating, or even reversing the biological. In contrast, an evolutionary analysis points out that the shot, through its careful targeting, picked out the particular cushion hit and the exact location hit. Over time, the selective retention of successful shots will organize the effect that the pre-existing environment had on the trajectories of the shots and the outcome of the game. The pre-existing structure of the world was exploited to impose an organization on the outcome that it would not otherwise have had.

In this same fashion, the evolutionary process explores and sifts the environment for aspects that will usefully organize the developing organism. The evolutionary process puts to work sources of organization and information anywhere they are unearthed, whether in the genes or in the environment, in a mother's smile or in a companion's expression of surprise. Selection has crafted the design of the developmental programs so that organisms tap into these reservoirs of information or hook themselves to environmental forces that help to construct them. Thus, the genomes of organisms have evolved to "store" organization and information that is necessary or helpful for development in the structure of the world itself. For example, for a developing child, the information in the minds of other humans, properly used, is a very useful source of information to use in their development, as are the linguistic patterns encountered in the local language community and patterns in local social behavior. Natural selection has intricately orchestrated developmental mechanisms so that things in the developmentally relevant world have been assigned an appropriate causal role, from gravity, plants, and three-dimensionality, to language, mothers, and social groups. Evolution shapes the relationship between the genes and the environment such that they both participate in a coordinated way in the construction and calibration of adaptations. Thus, evolutionarily patterned structure is coming in from the environment, just as much as it is coming out from the genes.

Accordingly, "biology" is not some substance that is segregated or localized inside the initial state of the organism at birth, circumscribing the domain to which evolutionary analyses apply. It is also in the organization of the developmentally relevant world itself, when viewed from the perspective imposed by the evolved developmental mechanisms of the organism. Thus, nothing the organism interacts with in the world is nonbiological to it, and so for humans cultural forces are biological, social forces are biological, physical forces are biological, and so on. The social and cultural are not alternatives to the biological. They are aspects of evolved human biology and, hence, they are the kinds of things to which evolutionary analysis can properly be applied.

Social scientists need to recognize that humans have evolved to expect, rely on, and take advantage of the richly structured participation of the environment—including the human social and cultural environment—in the task of adaptive development. Our developmental and psychological programs evolved to invite the social and cultural worlds in, but only the parts that tended, on balance, to have adaptively useful effects. Programs governing psychological development impose conceptual frameworks on the cultural and social worlds; choose which parts of the environment are monitored; choose how observations and interactions are categorized, represented, and interrelated; decide what entities to pursue interactions with; and, most importantly, determine what algorithms or relationships will organize environmental input into developmental change or psychological output. Consequently, the study of developmental adaptations is a central branch of evolutionary psychology. Understanding these adaptations will make visible the subtly stable structure of the developmentally relevant world and illuminate the evolutionary patterning in how human beings respond to smiles, to language, and to the cultural knowledge in others' minds. Each human, by expressing his or her species-typical architecture, contributes to the environmental regularities that others inhabit and rely on for their development.

For these reasons, it is a complete misconception to think that an adaptationist perspective denies or in the least minimizes the role of the environment in human development, psychology, behavior, or social life. Environmentalists have been completely correct about the importance of environmental input in the explanation of human behavior. Humans more richly and complexly engage the variable features of the environment than any other species we know of. It is this perception that has maintained environmentalism as the predominant viewpoint in the social sciences, despite its crippling inadequacies as an analytic framework. The terms "culture," "socialization," "intelligence," and "learning" are labels for poorly understood families of processes that reflect this complex and overwhelming human engagement with environmental inputs. Any viable theory of the evolved architecture of humans must reflect this reality and must be environmentalist in this sense. As discussed, the incoherence of Standard Model environmentalism stems from (1) the widespread failure to recognize that environmental responsiveness requires a complex evolved design (expressible as either a set of developmental adaptations or as a reliably developing psychological architecture; (2) the refusal to investigate or specify the nature of this architecture or these programs; and (3) the failure to recognize that the regulatory structure of these programs specifies the relationship between environmental input and behavioral, developmental, or psychological output.

For social scientists, of course, this recognition requires a radical change in practice: Every "environmentalist" explanation about the influence of a given part of the environment on humans will—if it is to be considered coherent—need to be accompanied by a specific "nativist" hypothesis about the evolved developmental and psychological mechanisms that forge the relationship between the environmental input and the hypothesized psychological output. All "environmentalist" theories necessarily depend upon and invoke "nativist" theories, rendering environmentalism and nativism interdependent doctrines, rather than opposed ones. For post-Standard Model researchers, these incoherent traditional dichotomies (genetic/environmental, biological/social, nativist/environmental) are being abandoned, as is reflected, for example, in the title of a recent article, "Learning by instinct" (J. Gould & Marler, 1987).

The Impact of the Recurrent Structure of Human Life and Human Culture on the Design of Psychological Adaptations

The evolved mesh between the information-processing design of human psychological adaptations, their developmentally relevant environments, and the stably recurring structure of humans and their environments is pivotal to understanding how an evolutionary psychological approach to culture differs from that of the Standard Social Science Model. For traditional anthropologists, cultures vary from place to place, and there is nothing privileged about a conceptual framework that categorizes human thought and action so as to capture underlying patterns of cross-cultural uniformity, as against the infinite class of perspectives by which human thought and behavior appear everywhere different (Geertz, 1973, 1983, 1984; see D. E. Brown, 1991, for a critique of this view). Nevertheless, from the "point of view" of natural selection, such uniformities—however subtle and unimportant to professionally neutral anthropological minds—are indeed privileged, and for a very simple reason. However variable cultures and habitats may have been during human evolution, selection would have sifted human social and cultural life (as well as everything else) for obvious or subtle statistical and structural regularities, building psychological adaptations that exploited some subset of these regularities to solve adaptive problems. (As we will discuss, one of the problems that had to be solved using regularities was the problem of learning "culture" itself.)

Thus, Geertz's starting point, that humans have evolved to use culture, is obviously true (although not in the slavish sense he envisions). But the next step in his logic—that humans don't have general cultures, only particular ones, and so evolved to realize themselves only through cultural particularity—is the error of naive realism. No instance of anything is intrinsically (much less exclusively) either "general" or "particular"—these are simply different levels at which any system of categorization encounters the same world. When you meet Roger Shepard you are, at one and the same time, meeting both a particular (and distinctive) individual and a manifestation of humanity in general, embodying innumerable species-typical characteristics. So it is with cultures. Selection operated across ancestral hominid populations according to what were, in effect, systems of categorization, screening cross-cultural variability for any recurrent relationships that were relevant to the solution of adaptive problems. To be thoroughly metaphorical, natural selection scrutinized the structure of human cultural and social environments, searching for regularities that could be used to engineer into our evolved architecture effective techniques for adaptive problem-solving. Thus, the issue is: During the Pleistocene, were there any statistical and structural uniformities to human life from culture to culture and habitat to habitat, from any perspective—no matter how subtle or abstract or unobservable—that could have been used by species-typical problem-solving machinery for the adaptive regulation of behavior and physiology? Geertz sees (modern) cultures as irredeemably particularized, confidently dismissing talk of meaningful human universals as nearly vacuous. Did natural selection "see" the human world the same way?

The answer is obvious, once the question is asked. Anthropological orthodoxy to the contrary, human life is full of structure that recurs from culture to culture, just as the rest of the world is. (Or, if one prefers, there are innumerable frames of reference within which meaningful cross-cultural uniformities appear, and many of these statistical uniformities and structural regularities could potentially have been used to solve adaptive problems.) Exactly which regularities are, in fact, part of the developmentally relevant environment that is used by our universal architectures is a matter to be empirically determined on a mechanism by mechanism, case by case basis. Such statistical and structural regularities concerning humans and human social life are an immensely and indefinitely large class (D. E. Brown, 1991): adults have children; humans have a species-typical body form; humans have characteristic emotions; humans move through a life history cued by observable body changes; humans come in two sexes; they eat food and are motivated to seek it when they lack it; humans are born and eventually die; they are related through sexual reproduction and through chains of descent; they turn their eyes toward objects and events that tend to be informative about adaptively consequential issues; they often compete, contend, or fight over limited social or subsistance resources; they express fear and avoidance of dangers; they preferentially associate with mates, children, and other kin; they create and maintain enduring, mutually beneficial individuated relationships with nonrelatives; they speak; they create and participate in coalitions; they desire, plan, deceive, love, gaze, envy, get ill, have sex, play, can be injured, are satiated; and on and on. Our immensely elaborate species-typical physiological and psychological architectures not only constitute regularities in themselves but they impose within and across cultures all kinds of regularities on human life, as do the common features of the environments we inhabit (see D. E. Brown, 1991, for an important exploration of the kinds and significance of human universals).

Human developmental mechanisms have been born into one cultural environment or another hundreds of billions of times, so the only truly long-term cumulatively directional effects of selection on human design would have been left by the statistical commonality that existed across cultures and habitats. Consequently, the sustained impact of these cross-culturally recurrent relationships sculpted the problem-solving mechanisms of the human mind to expect and exploit the common structure of human cultures and human life; that is, natural selection constructed adaptations specialized to mesh with the detailed structural regularities common to our ancestral cultural environments. For this reason, not only does natural selection privilege frames of reference that reveal patterns of universality in human life but our evolved psychological architecture does also. Embedded in the programming structure of our minds are, in effect, a set of assumptions about the nature of the human world we will meet during our lives. So (speaking metaphorically) we arrive in the world not only expecting, Geertzian fashion, to meet some particular culture about whose specifically differentiated peculiarities we can know nothing in advance. We also arrive expecting to meet, at one and the same time, and in one and the same embodiment, the general human culture as well—that is, recognizably human life manifesting a wide array of forms and relations common across cultures during our evolution (or at least some set out of the superset). Thus, human architectures are "pre-equipped" (that is, reliably develop) specialized mechanisms that "know" many things about humans, social relations, emotions and facial expressions, the meaning of situations to others, the underlying organization of contingent social actions such as threats and exchanges, language, motivation, and so on.

To take only one example, humans everywhere include as part of their standard conceptual equipment the idea that the behavior of others is guided by invisible internal entities, such as "beliefs" and "desires"—reflecting what Dennett calls "the intentional stance" (1987). Of course, this way of thinking seems so natural to us that it is difficult to see that there is anything to explain: It is tempting to think that beliefs and desires are "real" and that, therefore, humans everywhere simply learn to see the world as it really is. Side-stepping the complex question of whether this panhuman folk psychology is an accurate way of capturing "real" human psychology (i.e., whether it is a true or a complete description), we simply want to point out that things such as beliefs and desires are inherently unobservable hidden variables used to explain observations that could be explained by any of an infinite set of alternative theories (in fact, psychologists have come up with many such theories). Therefore, a belief in beliefs and desires cannot be justified by observations alone, so the fact that it is conventional among humans to "theorize" about others in this fashion is not inexorably mandated by their experience or otherwise required by the structure of the external world. For the same set of nonmandated ideas to have emerged everywhere on earth, our developmental programs or cognitive architectures must impose this way of interpreting the world of other humans on us.

In fact, an intensive research effort in the field of cognitive development has recently provided substantial support for the hypothesis that our evolved psychological architecture includes procedures that cause very young children to reliably develop a belief-desire folk psychology—a so-called "theory of mind" (e.g, Astington, Harris, & Olson, 1988; Leslie, 1987, 1988; Perner, 1991; Wellman, 1990; Wimmer & Perner, 1983). Developmental psychologists have been finding that even 2- and 3-year-olds make different inferences about "mental entities" (dreams, thoughts, desires, beliefs) than about "physical entities." Moreover, children typically "explain" behavior as the confluence of beliefs and desires (e.g., Why has Mary gone to the water fountain? *Because* she has a *desire* for water (i.e., she is thirsty) and she *believes* that water can be found at the water fountain). Such inferences appear to be generated by a domain-specific cognitive system that is sometimes called a "theory of mind" module (Leslie, 1987). This module consists of specialized computational machinery that allows one to represent the notion that "agents" can have "attitudes" toward "propositions" (thus, "Mary" can "believe" that "X," "Mary" can "think" that "X," and so on). Between the ages of 3 and 5 this domain-specific inferential system develops in a characteristic pattern that has been replicated cross-culturally in North America, Europe, China (Flavell, Zhang, Zou, Dong & Qui, 1983), Japan (Gardner, Harris, Ohmoto & Hamazaki, 1988), and a hunter-gatherer group in Camaroon (Avis & Harris, in press). Moreover, there is now evidence suggesting that the neurological basis of this system can be selectively damaged; indeed, autism is suspected to be caused by a selective neurological impairment of the "theory of mind" module (Baron-Cohen, Leslie, & Frith, 1985; Leslie, 1987, 1988; Leslie & Thaiss, 1990).

This research indicates that a panhuman "theory of mind" module structures the folk psychology that people develop. People in different cultures may elaborate their folk psychologies in different ways, but the computational machinery that guides the development of their folk notions will be the same, and some of the notions developed will be the same as well. Humans come into the world with the tendency to organize their understanding of the actions of others in terms of beliefs and desires, just as they organize patterns in their two-dimensional retinal array under the assumption that the world is three-dimensional and that objects are permanent, bounded, and solid.

Thus, not only do evolved mechanisms assume certain things will tend to be true of human life but these specialized procedures, representational formats, cues, and categorization systems impose—out of an infinite set of potential alternatives—a detailed organization on experience that is shared by all normal members of our species. There is certainly cultural and individual variability in the exact forms of adult mental organization that emerge through development, but these are all expressions of what might be called a single human metaculture. All humans tend to impose on the world a common encompassing conceptual organization, made possible by universal mechanisms operating on the recurrent features of human life. This is a central reality of human life and is necessary to explain how humans can communicate with each other, learn the culture they are born into, understand the meaning of others' acts, imitate each other, adopt the cultural practices of others, and operate in a coordinated way with others in the social world they inhabit. By *metaculture*, we mean the system of universally recurring relationships established and constituted by (1) our universal evolved species-typical psychological and physiological architectures, (2) the interaction of these architectures with each other in populations, (3) their interaction with the developmentally relevant recurrent structure of human natural and cultural environments, and (4) their patterned standard impact on human phenomena.

Social scientists have traditionally considered there to be a tension or explanatory competition between human universals and transmitted cultural variability: the more of one, the less of the other (D. E. Brown, 1991). However, careful causal analysis of the information-processing tasks required to learn transmitted culture leads to what is very nearly the opposite conclusion. In fact, it is only the existence of this common metacultural structure, which includes universal mechanisms specialized to mesh with the social world, that makes the transmission of variable cultural forms possible.

To make this clear, consider the question of how it is possible for pre-linguistic children to deduce the meanings of the words they hear when they are in the process of learning their local language for the first time. The child's task of discovering the meanings of words involves isolating, out of an infinite set of possible meanings, the actual meanings intended by other speakers (e.g., Carey, 1982, 1985a; Quine, 1960). Children can infer the meanings of messages in the local, but unknown language only because they, like cryptographers, have a priori statistical knowledge about likely messages, given the situational context. To solve the problem of referential ambiguity, the child's procedures for semantic analysis must depend on the fact that our universal evolved psychological architectures impose on the world enough standard and recurrent interpretations between speaker and listener to make the deduction of a core lexicon possible. Since the infant is new to the culture and ignorant of it, these shared interpretations cannot be supplied by the culture itself, but must be supplied by the human universal metaculture the infant or child shares with adults by virtue of their common humanity. (In contrast, the Standard Model's initially content-free general process child mind would share no common interpretations with local adults and could rely on no necessary imposition of common event construals by both speaker and listener.) Thus, the system for assigning correct semantic meanings to culturally arbitrary signs necessarily relies on the presence of species-typical cognitive adaptations and on the nonarbitrariness of meaning systems that inhabit these cognitive adaptations. These mechanisms reliably identify evolutionarily recurrent situations (such as threat, play, or eating) in such a way that the participants have similar construals of the situation and responses to it, including things likely to be said about it.

For example, children who are just learning their local language interpret novel words using Markman's "whole object assumption" and her "taxonomic assumption." The whole object assumption causes them to interpret the novel word "cup" as referring to a whole cup, and not to its handle, the porcelain it is made of, a cup on a saucer, a cup of tea (and so on); the "taxonomic assumption" causes them to interpret "cup" as referring to all objects of the same type, and not to the particular cup being pointed to at that moment (Markman, 1989; Markman & Hutchinson, 1984). Of course, the operation of these assumptions depends, in turn, on interpretations generated by the kinds of domain-specific inferential systems discussed earlier, which define what entities and relations count as whole objects, animals, plants, people, natural kinds, artifacts, taxonomic categories, and so on (Carey & Gelman, 1991). Still other domain-specific reasoning procedures may privilege certain interpretations of social relations. Thus, social contract algorithms have both intrinsic definitions for the terms used by their procedures and cues for recognizing which elements in recurrent situations correspond to those terms (Cosmides, 1989; Cosmides & Tooby, 1989, this volume). Consequently, these evolved reasoning specializations may sometimes function as nuclei around which semantic inference is conducted. Emotional expressions also function as metacultural cues that assign standardized meanings to the contingent elements of situations (see Fernald, this volume; Tooby & Cosmides, 1990b). For example, if someone reacts with fear, others interpret this as a reaction to danger and attempt to identify in the situation what the dangerous entity is, re-evaluating various stimuli. They may scan the local environment, organizing their search by a categorization system that privileges some things (e.g., snakes) over others (e.g., flowers) (Cook, Hodes, & Lang, 1986).

Thus, we have the surprising result that it is the shared species-typical mechanisms and common metacultural framings that make it possible for a child to learn what is culturally variable: in this case, the meanings of words in the local language. This argument, in fact, generalizes beyond language: The variable features of culture can be learned solely because of the existence of an encompassing universal human metaculture. The ability to imitate the relevant parts of others' actions (Meltzoff, 1988), the ability to reconstruct the representations in their minds, the ability to interpret the conduct of others correctly, and the ability to coordinate one's behavior with others all depend on the existence of human metaculture. Sperber and Wilson (1986) have written at length about how, for successful communication to be possible, both sender and receiver must share a great many assumptions about the world. The less they mutually assume, the more difficult it is to communicate until, in the limiting case, they cannot communicate at all. The child arrives in the culture free of any knowledge about its particularities, and so the only way the child initially can be communicated with is through what is mutually manifest between the child and the adults by virtue of their common humanity (e.g., Fernald, this volume). The same is true, as Sperber (1982) concisely points out, of ethnographers: The best refutation of cultural relativity is the activity of anthropologists themselves, who could not understand or live within other human groups unless the inhabitants of those groups shared assumptions that were, in fact, very similar to those of the ethnographer. Like fish unaware of the existence of water, interpretativists swim from culture to culture interpreting through universal human metaculture. Metaculture informs their every thought, but they have not yet noticed its existence.

So the beginning of this section, in which we discussed how natural selection sifted cultural variability throughout the Pleistocene for uniformities, gave only a one-sided analysis of how, despite cultural variability, universals still existed. It is even more important to realize that contentful human universals make possible the very existence of transmitted cultural variability (what is usually called "culture"), which would otherwise be impossible. Therefore, the development of increasing cultural variation throughout the Pleistocene was made possible by the evolution of psychological specializations that exploited the regularities of human metaculture in order to learn the variable features of culture. To return to a position William James stated a century ago, to behave flexibly, humans must have more "instincts" than other animals, not fewer.

THE TRANSITION TO POST-STANDARD MODEL PSYCHOLOGY

The Decline of Standard Model Psychology

The progression from Standard Model psychology to post-Standard Model psychology was driven largely by the emergence of new and more rigorous standards that psychological theories are now expected to meet. As the field grew more sophisticated, various communities of psychologists began insisting on *causal accounts* of how hypothesized Standard Model mechanisms produced their effects: What are the networks of cause and effect that, step by step, lead from input to output? In the social sciences, no model of the human psychological architecture seemed impossible when its proponents didn't have to specify by what methods it generated human behavior. The cognitive revolution, with its emphasis on formal analysis, made clear that theories needed to be made causally explicit to be meaningful, and it supplied psychologists with a far more precise language and set of tools for analyzing and investigating complexly contingent, information-responsive systems. When examined from this perspective, most traditional theories turned out to be both incomplete and incapable of accounting for large classes of observed phenomena. Indeed, most no longer seemed to qualify as hypotheses at all. For example, "learning" ceased to be seen as an explanation for behavior, but instead was recognized as a label for a loosely defined class of phenomena generated by as yet unknown procedures. For modern psychologists the key question became: What is the explicit description of these procedures?

Over the last three decades, the hard work of discovering procedures that could actually account in detail for observed behavior and competences has led to the widespread conclusion that our evolved psychological architecture must include a large set of mechanisms of a very different character than Standard Model psychologists had envisioned. The most fundamental shift from Standard Model to post-Standard Model psychology has been the abandonment of the axiom that evolved psychological mechanisms must be largely—or exclusively—general-purpose and free of any contentful structure not put there by experience (e.g., Carey & Gelman, 1991; Chomsky, 1975; Cosmides & Tooby, 1987, 1992; Gallistel, 1990; Gigerenzer, 1991b; Gigerenzer & Murray, 1987; Herrnstein, 1977; Pinker, 1984; Rozin, 1976; Rozin & Schull, 1988; Shepard, 1984, 1987a; Symons, 1987). Many psychologists have been forced by their data to conclude that both human and nonhuman minds contain—in addition to whatever general-purpose machinery they may have—a large array of mechanisms that are (to list some of the terms most frequently used) functionally specialized, content-dependent, content-sensitive, domain-specific, context-sensitive, special-purpose, adaptively specialized, and so on. Mechanisms that are functionally specialized have been called (with some differences in exact definition) adaptive specializations by

Rozin (1976), modules by Fodor (1983), and cognitive competences or mental organs by Chomsky (1975, 1980).

Consequently, the core of the debate is not really about whether the reliably developing design of the mind evolved—the answer to that question can only be yes. The debate is, instead, over whether our evolved psychological architecture is predominantly domain-general (Symons, 1987). Did the human mind evolve to resemble a single general-purpose computer with few or no intrinsic content-dependent programs (e.g., Gould, 1979)? Or does its evolved architecture more closely resemble an intricate network of functionally dedicated computers, each activated by different classes of content or problem, with some more general-purpose computers embedded in the architecture as well (e.g., Chomsky, 1975, 1980; Cosmides & Tooby, 1987; Gallistel, 1990; Gazzaniga, 1985; Rozin, 1976; Symons, 1987)? In other words, does the human mind come equipped with any procedures, representational formats, or content-primitives that evolved especially to deal with faces, mothers, language, sex, food, infants, tools, siblings, friendship, and the rest of human metaculture and the world?

Solvability and the Formal Analysis of Natural Competences

Thirty years ago, Noam Chomsky inaugurated a new era in the behavioral sciences when he began to explore psychological questions by analyzing the capacities of well-specified computational systems (Chomsky 1957, 1959). His approach was distinctive. To evaluate existing psychological theories, he first made their underlying assumptions about computational mechanisms explicit. He then tested the ability of these computational mechanisms to solve real, natural problems that humans were known to be able to solve. In his first application of this method, he attempted to evaluate the adequacy of behaviorist accounts of language, particularly as presented in Skinner's then recently published book, *Verbal Behavior* (1957). When Chomsky examined the behaviorist account of language in the light of these criteria, he found that it suffered from a series of difficulties that precluded it from being a persuasive explanation for human linguistic competence.

Chomsky's research program brought the serious deficiencies of the Standard Model into plain view because it combined two key ingredients: (1) the study of tasks related to a natural, complex, real-world competence that humans were known to have, and (2) the use of formal solvability analyses to explore the actual computational capacities of mechanisms hypothesized to generate explicitly defined outcomes. A theory about the design of a mechanism cannot be correct if, under the relevant conditions, that design cannot solve the problem or generate the performance that the theory claims it can; this can be determined using a solvability analysis, as outlined in pp. 73–77.

Language was a pivotal choice for a test of domain-general accounts of behavior because language—particularly syntax—involved complex but clearly specifiable patterns of behavior that humans were already known to be able to produce under natural conditions without elaborate experimental manipulations. Within this domain, one could precisely and unambiguously define criteria for recognizing what behavioral patterns humans could and did routinely produce (grammatical versus ungrammatical sentences). Therefore, one could define what output any mechanism hypothesized to account for these behavioral patterns had to produce as well. In contrast, no one could tell whether associationist mechanisms or general-purpose symbol-processing mechanisms could account for phenomena such as "religion," "marriage," or "politics" because no one had an unambiguous empirical definition of human performance in these spheres.

By specifying what counts as the production of grammatical utterances or the acquisition of the grammar of a human language, psycholinguists working within the Chomskyan research tradition have been using solvability analyses to show that a task routinely mastered by four-year-old children is too richly structured to be accounted for by any known general-purpose mechanism operating in real time (Chomsky, 1975, 1980; Pinker, 1979, 1984, 1989, 1991; Pinker & Bloom, this volume; Wexler & Culicover, 1980). Despite three decades of intensive efforts by Standard Model psychologists to get general-purpose cognitive machinery to learn grammar, their theories have fared no better than did their behaviorist predecessors. To take a recent example, through careful solvability analyses, Pinker and Prince were able to show that newly proposed domain-general connectionist and associationist models were computationally insufficient to solve even so narrow a problem as the acquisition of the past tense in English (Pinker, 1991; Pinker & Prince, 1988). These mechanisms failed precisely because they lacked computational machinery specialized for the acquisition of grammar.

Thirty years of such findings have forced many cognitive psychologists, against their inclination, to accept domain-specific hypotheses about language learning—to conclude that humans have as part of their evolved design a language acquisition device (LAD), which incorporates content-dependent procedures that reflect in some form "universal grammar" (Chomsky, 1975, 1980; Pinker, 1979, 1984, 1989, 1991; Wexler & Culicover, 1980). In this view, the architecture of the human mind contains content-specialized mechanisms that have evolved to exploit the subtle cross-culturally recurring features of the grammars of human language communities—one facet of human metaculture (Pinker & Bloom, this volume).

The introduction of solvability analyses and the increasing demand for well-specified information-processing models have exposed the deficiencies of Standard Model theories in other areas of psychology as well (see, e.g., Carey & Gelman, 1991; Cosmides, 1989; Cosmides & Tooby, 1989, this volume; Gelman & Markman, 1986, 1987; Keil, 1989; Leslie, 1987; Markman, 1989). Standard Model theories are usually so underspecified that one cannot make their underlying assumptions about computational mechanisms procedurally explicit. To the extent that they can be evaluated, however, when they are faced with real world tasks that humans routinely solve, they consistently perform poorly or not at all.

In fact, the large-scale theoretical claims of Standard Model psychology never had a strong empirical base. Limited empirical support could be produced for Standard Model domain-general theories, but only so long as research was confined to the investigation of experimenter-invented, laboratory limited, arbitrary tasks. The occasional matches between domain-general theories and data sets have been chronically weak and experimentally fragile. These restricted empirical successes depended on carefully picked experimental venues, such as pigeons isolated from conspecifics pecking for food in stimulus-depauperated environments or humans learning lists of nonsense syllables. Standard Model theories of mechanisms have maintained themselves as empirically credible primarily through pretheoretical decisions concerning what kinds of experiments were considered meaningful and through assumptions imposed a priori on the class of hypotheses that would be entertained. For humans and nonhumans alike, exposure to biologically significant stimuli and natural tasks elicits complexly patterned performances that Standard Model theories are unable to predict or explain. So, to keep behavioral phenomena in line with theory, Standard Model psychologists had to keep humans and other species outside of ecologically valid circumstances, away from any biologically significant stimuli, and test them on artificial problems that subjects would not have had to solve in their environment of evolutionary adaptedness (for discussion, see Beach, 1950; Breland & Breland, 1961; Herrnstein, 1977; Lockard, 1971). Although these weaknesses have now mostly been abandoned in the study of other species, they unfortunately remain endemic in many areas of human psychology.

Once animal behavior researchers let the pigeon out of its barren artificial cage, a rich flock of behavioral phenomena appeared, and questions inevitably arose about the mechanisms that guide the animal to do all the different things it needs to do in natural environments to survive and reproduce. Thus, ethology (or behavioral ecology, sociobiology, or animal behavior) played an important corrective role by providing examples of the tasks organisms solve and the complex performances they exhibit in more natural conditions (Daly & Wilson, 1984b; Krebs & Davies, 1984; Lorenz, 1965; Rozin & Schull, 1988; Tinbergen, 1951; Wilson, 1975). These fields carefully documented functionally interpretable behaviors that lie far outside anything that Standard Model psychology and a short list of drives could explain. Researchers investigating the now well-known selection pressure expressed by Hamilton's rule (see pp. 67–68) documented an enormous array of kin-directed assistance in nonhuman animals—behaviors completely undreamed of in Standard Model psychology (Hamilton, 1964; Williams & Williams, 1957; for review, see Krebs & Davies, 1984). Infant macaques become emotionally attached to immobile cloth figures even though they nurse ("are reinforced") on another structure entirely (Harlow, Harlow, & Suomi, 1971). There are reports from an entire range of species—from langurs to lions to rodents—of newly resident males killing the unweaned infants of their predecessors, thereby accelerating ovulation in their new mates (Hrdy, 1977; Hausfater & Hrdy, 1984). Ring doves may expend considerable effort to monitor the sexual behavior of their mates (Erickson & Zenone, 1976). There was the discovery of the complex patterns of food reciprocation in vampire bats—phenomena difficult to account for using traditional notions of general-purpose cognition, conditioning, and drive reduction (e.g., Wilkinson 1988, 1990). From echolocation to parental care, to celestial navigation, to courtship, to coalitional action in chimpanzees, to seasonal migration, to decoying predators away from nests, to communication in bees, to "friendship" and dominance in baboons, nonhuman behavior is full of tasks and organized behaviors that do not remotely fit into Standard Model psychology. This burgeoning body of phenomena caused many animal behavior researchers to break away from the narrow experimental paradigms and narrow questions of the Standard Social Science Model.

In human psychology, the observational basis for Standard Model theories was equally circumscribed, but escape from its narrow experimental paradigms has been more difficult than in nonhuman psychology. Standard Model psychologists had no salient reason for suspecting that different psychological mechanisms would be activated by different kinds of tasks. Human activities appeared to be so variable—both between cultures and among individuals within a culture—that the notion that some tasks and problems might be more "natural" than others did not seem conspicuously sensible. Although most psychologists were faintly aware that hominids lived for millions of years as hunter-gatherers or foragers, they did not realize that this had theoretical implications for their work. More to the point, however, the logic of the Standard Social Science Model informed them that humans were more or less blank slates for which no task was more natural than any other. Until the emergence of a community of Chomskyan psycholinguists, mainstream psychology had been overwhelmingly dominated by general-purpose learning and cognitive theories. In consequence, the same processes were assumed to account for learning and action in all domains of human activity, from suckling at the breast to incest avoidance, language learning, and alliance negotiations among Dani warriors.

By questioning the assumption that all tasks were created equal, Chomsky exposed how narrowly chosen Standard Model research topics had actually been and how overreaching the extrapolation had been from these topics to the rest of human thought and action. The rise of Chomskyan psycholinguistics constituted a decisive turning point in the development of human psychology because it introduced the subversive idea that some tasks might awaken associated competences that were more "natural" than others: more functionally specialized, more complex, more reliably developing, more species-differentiated, and, therefore, more worthy of detailed exploration (Marr & Nishihara, 1978).

The Rise of Domain-Specific Psychology

The Chomskyan revolution in the study of language slowly began to legitimize the exploration of models of our evolved psychological architecture that did not assume a priori that all tasks are solved by the same set of content-independent processes. In diverse subcommunities, the gradually expanding freedom to consider domain-specific hypotheses alongside more orthodox ones has led to their increasing acceptance. Performance in virtually every kind of experimental situation is sensitive to the content and context of the task, and domain-specific hypotheses tend to organize, account for, and predict this performance better than their Standard Model predecessors. Although social and behavioral scientists outside of cognitive, comparative, and physiological psychology still routinely assume a domain-general human mind, within the community of psychologists who rigorously study mechanisms this view is in retreat and disarray. Standard Model psychology has been able to persist only in those research communities that avoid formal analysis entirely or that avoid using it to study performance on ecologically valid, natural tasks.[6]

Thus, researchers who ask hard questions about how organisms actually solve problems and who focus on the real performance of organisms on natural tasks have had to abandon the idea that the mind is free of content-specialized machinery. Researchers who study color vision, visual scene analysis, speech perception, conceptual development in children, mental imagery, psychophysics, locomotion, language acquisition, motor control, anticipatory motion computation, face recognition, biomechanical motion perception, emotion recognition, social cognition, reasoning, and the perception and representation of motion, for example, cannot account for the psychological phenomena they study by positing computational mechanisms that are solely domain-general and content-independent (see, e.g., Bizzi, Mussa-Ivaldi, & Gizster, 1991; Carey & Gelman, 1991; Etcoff, 1986; Freyd, 1987; Kosslyn, 1980; Liberman & Mattingley, 1985, 1989; Lindblom, 1986, 1988; Maloney & Wandell, 1985; Marr, 1982; Pinker, 1984, 1989; Poggio et al., 1985; Proffitt & Gilden, 1989; Shepard, 1981, 1984, 1987a; Shiffrar & Freyd, 1990; Spelke, 1988, 1990). In fact, the reality has always been that every field of psychology bristles with observations of content-dependent phenomena. Freedom from the axiom that all psychological phenomena must be explained by content-independent machinery has allowed psychologists to move ahead to explore—and to view as meaningful—the rich content-sensitive effects that permeate psychological phenomena (e.g., Astington et al., 1988; A. Brown, 1990; Carey, 1985b; Carey & Gelman, 1991; Cosmides, 1989; Cosmides & Tooby, this volume; Gelman & Markman, 1986, 1987; Gigerenzer & Hug, in press; Gigerenzer & Murray, 1987; Keil, 1989; Manktelow & Over, 1991). Formerly, these omnipresent content effects were considered an embarrassment to be explained away or else dismissed as noise. Now they are considered to be primary data about the structure of the mind.

Outside of cognitive psychology, the emergence of post-Standard Model approaches derived their impetus from branches of evolutionary biology. In the 1950s and 1960s, the successful application of evolutionary approaches to animal behavior in ethology and its successor disciplines provided evidence of domain-specific mechanisms that was difficult to ignore (e.g., attachment, emotion, phobias, mating, foraging, navigation). This trend was accelerated by the rapid advances in evolutionary biology over the last three decades, which made the previously clouded connection between evolution and behavior somewhat clearer. These advances included (1) more coherent approaches to the nature-nurture issue, (2) a more rigorous foundation for the theory of natural selection (Williams, 1966), (3) formal analyses of what behaviors would be favored by selection in a variety of newly explored domains (e.g., Charnov, 1976; Hamilton, 1964; Maynard Smith, 1982; Stephens & Krebs, 1986; Trivers, 1971, 1972, 1974; Williams, 1966), and (4) a cascade of successful applications of these theories to animal behavior (Alexander, 1974; Daly & Wilson, 1984b; Krebs & Davies, 1984; Wilson, 1975).

Just as in the case of nonhuman behavior, evolutionarily informed studies of human choice, motivation, emotion, and action also bristle with documented phenomena that cannot be accounted for with content-independent architectures and a short list of drives, rewards, or reinforcers (the chapters in this volume are a small sampling of such cases). For example, ever since the Harlows demolished the myth that an infant's love for its mother was a conditioned response to food rewards, the rich collection of co-adapted mechanisms in the mother and infant has been a productive focus of psychological investigation (e.g., Bowlby, 1969). Profet (this volume) identifies a maternal psychological adaptation for the protection of the fetus during embryogenesis. Fernald (this volume) explores the communicative adaptations mothers have to the infant's perceptual limitations. Moreover, cross-cultural regularities in fall-rise patterns of maternal fundamental frequency provide an elegant illustration that a child and adult initially communicate by virtue of what they share through their common human metaculture. Communication through such human universals is a precondition for the child's acquisition of the culturally specific. Facial expressions of emotion represent another evolved modality through which humans communicate situation-construals, and the cross-culturally stable features of emotional expression provide another critical foundation for human metaculture. Ekman and his colleagues have established one of the earliest and most sophisticated traditions of evolutionary psychological research, and these studies of emotional expression represent a major achievement in modern psychology (e.g., Ekman, 1973, 1982, 1984; Ekman & Friesen, 1975; Ekman, Levenson, & Friesen, 1983). Etcoff (1986) has marshalled substantial neuropsychological evidence that humans have mechanisms specialized for the identification of emotional expression—an adaptation to an important, stable feature of ancestral social and cultural environments.

Indeed, ever since Darwin (1871, 1872), emotions have been seen as the product of the evolutionary process and usually, although not always, as functional adaptations (e.g., Arnold, 1960, 1968; Chance, 1980; Daly, et al., 1982; Eibl-Eibesfeldt, 1975; Ekman, 1982; Frijda, 1986; Hamburg, 1968; Izard, 1977; Otte, 1974; Plutchik, 1980; Tomkins, 1962, 1963; Tooby & Cosmides, 1990b; and many others). Functional or not, the emotions collectively provide a dense and pervasive network of domain-specific phenomena that have consistently resisted assimilation into any Standard Model theory. However, in contrast to their Standard Model reputation as crude and indiscriminate responses, on close scrutiny each specific emotion appears to be an intricately structured information-sensitive regulatory adaptation. In fact, the emotions appear to be designed to solve a certain category of regulatory problem that inevitably emerges in a mind full of disparate, functionally specialized mechanisms—the problem of coordinating the menagerie of mechanisms with each other and with the situation being faced (Tooby, 1985; Tooby & Cosmides, 1990b; Nesse, 1990).

Daly and Wilson have been exploring the evolved complexity and functional subtlety of the human motivational system. They have produced a substantial body of findings supporting specific hypotheses they derived from a broad array of adaptationist theories (Daly & Wilson, 1981, 1982, 1984b, 1987a, 1987b, 1988; Daly, et al., 1982; Wilson & Daly, 1985, 1987, this volume). Their particular interest has been the evolved motivational systems that regulate parental care, spousal relations, sexual jealousy, sexual proprietariness, and risk-taking. By using behavioral phenomena such as violence and homicide as dependent measures, they have been able to investigate many aspects of these evolved motivational systems—including how their operation is affected by factors such as gender, age, kinship, reproductive value, number of children, and other situational variables (see also Mann, this volume). Similarly, in the area of human mate choice and sexuality, the work of Symons, Buss, and many others shows that the construct of a "sex drive" is completely inadequate to cope with the structured richness of the situational factors processed by the differentiated sexual psychologies of men and women across cultures (e.g., Buss, 1987, 1989, 1991, this volume, in prep.; Ellis, this volume; Sadalla, Kenrick, & Vershure, 1987; Symons, 1979; Townsend, 1987). These studies indicate that existing theories of motivation will have to be replaced with theories positing a far more elaborate motivational architecture, equipped with an extensive set of evolved information-processing algorithms that are contingently sensitive to a long list of situational contents and contexts.

Thus, the examination of even a small sampling of non-Standard Model behavioral studies by a handful of researchers such as Bowlby, Daly and Wilson, Ekman, Fernald, Marks, Buss, and Symons leads to the conclusion that the human mind contains evolved emotional and motivational mechanisms that are specifically targeted to address adaptive problems involved in parenting, emotional communication with infants and adults, kinship, mate choice, sexual attraction, aggression, the avoidance of danger, mate guarding, effort allocation in child care, and so on. That is, humans have psychological adaptations that contain contentful structure specifically "about" their mothers, "about" their children, "about" the sexual behavior of their mates, "about" those identified by cues as kin, "about" how much to care for a sick child, and so on, and these contents are not derived exclusively from either a short list of drives or from culturally variable, socially learned "values."

In short, the central tenets of Standard Model psychology are contradicted by results from a large and rapidly growing body of research on humans and nonhumans from the cognitive community, from the evolutionary community, from the behavioral ecology community, and from other research communities as well (for example, much of psychobiology, comparative psychology, and neuroscience). Content-independent mechanisms simply cannot generate or explain the richly patterned behaviors and knowledge structures that appear when one's research focus is widened beyond arbitrary laboratory tasks to include the complex performances orchestrated by natural competences on real world tasks. Moreover, unlike most Standard Model theories and results, these kinds of studies and hypotheses withstand cross-cultural scrutiny and indicate that a great deal of the substance of social life attributed to "culture" around the world is in fact caused by the operation of contingently responsive domain-specific mechanisms. These converging results are accumulating into a strikingly different picture than that provided by the Standard Social Science Model. They indicate that a universal, evolved psychological architecture that is filled with contingently responsive mechanisms infuses distinctively human patterns into the life of every culture.

The Frame Problem and the Weakness of Content-Independent, Domain-General Mechanisms

From Flexibility to Adaptive Flexibility

In the passage from Standard Model to post-Standard Model psychology it seems fair to say that the greatest reversal lay in how content-independence and domain-generality came to be regarded. Many modern researchers recognize that content-independent, general problem-solvers are inherently weak in comparison to content-specialized mechanisms. From a traditional point of view, however, it seemed sensible to regard generality as an enhancement of the capacity of a system: The system is not prevented from assuming certain states or kept from doing what is adaptive (or desirable) by a "rigid" or "biased" architecture. Generality of application seems like such an obvious virtue and content-independence seems like such an obvious road to flexible behavior, what could possibly be wrong with them? As Marvin Harris puts this line of reasoning, "Selection in the main has acted against genetically imposed limitations on human cultural repertoires" (1979, p. 136). Why rigidly prevent the system from engaging in certain behaviors on those occasions when they would be advantageous? Moreover, why not have an "unbiased" architecture in which the actual structure of local circumstances impresses a true picture of itself in a free, objective, and unconstrained way? In this view, content-specificity in evolved psychological design is imbued with all the legendary attributes of "biology"—rigidity, inflexibility, and constraint. It is viewed as preventing the system from achieving advantageous states that would otherwise naturally come about.

So what, after all, is so wrong with domain-general systems? Why do cognitive psychologists and artificial intelligence researchers consistently find them too weak to solve virtually any complex real world task? Why isn't "flexibility" in the form of content-independence a virtue? The answers to these questions emerge from one clarification and from two basic facts. The two facts have already been touched on many times: (1) possibilities are infinite; and (2) desirable outcomes—by any usual human, evolutionary, or problem-solving standard—are a very small subset of all possibilities.

The clarification concerns the kind of plasticity and flexibility that are implicitly being referred to. Literally, plasticity, or flexibility, is the simple capacity to vary in some dimension. The more dimensions of possible variation, the greater the "plasticity." Hence, a lump of clay is very plastic with respect to shape (although not with respect to substance, density, and so on). Similarly, there is an infinite number of ways that humans and other animals could potentially act. The difficulty lies in the fact that the overwhelming majority of behavioral sequences would be lethal in a few hours, days, or weeks. The set of behaviors that leads even to temporary individual survival—let alone to reproduction or design-propagation—constitutes an extremely miniscule subset of all possible behavioral sequences. Thus, the property of freely varying behavior in all dimensions independent of conditions is not advantageous: It is evolutionarily and individually ruinous.

Accordingly, to be endowed with broad behavioral plasticity unconnected to adaptive targets or environmental conditions is an evolutionary death sentence, guaranteeing that the design that generates it will be removed from the population. Designs that produce "plasticity" can be retained by selection only if they have features that guide behavior into the infinitesimally small regions of relatively successful performance with sufficient frequency. In reality, terms such as flexibility or plasticity are implicitly used to mean something very different from the simple "capacity to vary." They are implicitly used to mean the capacity to adjust behavior (or morphology) as a coordinated response to the specifics of local conditions so that the new behavior is particularly appropriate to or successful in the specific circumstances faced.

This narrowly specialized form of flexibility requires three components: (1) a set of mechanisms that define an adaptive target (such as finding food, finding home, or finding a mate); (2) a set of mechanisms that can compute or otherwise determine what responses are most likely to achieve the adaptive target in each specific set of circumstances that one is likely to encounter; and (3) the ability to implement the specific response once it is determined. Plasticity in the "lump of clay/capacity to vary" sense refers only to the third component: If an organism has correctly computed what it is advantageous to do, then (and only then) is it disadvantageous to be inflexibly prevented from implementing those changes by some fixed element of the system.

In fact, plasticity (e.g., variability) tends to be injurious everywhere in the architecture except where it is guided by well-designed regulatory mechanisms that improve outcomes or at least do no harm. It would be particularly damaging if these regulatory mechanisms were themselves capriciously "plastic," instead of rigidly retaining those computational methods that produce advantageous responses to changing conditions. Thus, plasticity is only advantageous for those specific features of the organism that are governed by procedures that can compute the specific changes or responses that will be, on average, more successful than a fixed phenotype. Adaptive flexibility requires a "guidance system" (Cosmides & Tooby, 1987; Tooby, 1985).

The most important conclusion to be derived from this line of reasoning is that adaptive flexibility can only evolve when the mechanisms that make it possible are embedded within a co-evolved guidance system. Consequently, the expansion of behavioral and cognitive flexibility over evolutionary time depended acutely on how well-designed these computational guidance systems became. There is nothing in the ability to vary per se that naturally leads systems to gravitate toward producing successful performances. It is the guidance system itself that is doing the bulk of the interesting regulation of outcomes, with the "potential to vary" component explaining very little about the situation. Thus, Gould's (1977a, 1979) faith in the explanatory power of the SSSM concept of generalized human "biological potential" depends either on (1) an unjustified teleological panglossianism (e.g., unguided processes, such as accidental brain growth, just happen to "work out for the best," giving humans the desire to care for their children, to defend themselves when attacked, to cooperate; the ability to recognize faces, to find food, to speak a language . . .), or (2) the unacknowledged existence of co-evolved cognitive adaptations that guide behavioral plasticity toward the achievement of adaptive targets.

It is the necessary existence of these co-evolved guidance systems that has, for the most part, escaped the attention of Standard Model advocates. In fact, the SSSM edifice is built on the conflation of two distinct notions of flexibility: (1) flexibility as the absence of any limits on responses, and (2) flexibility as the production of contextually appropriate responses. Advocates of the SSSM imagine that flexibility in the first sense—an absence of limits on variation—is easy to computationally arrange (just remove all "constraints"). But they also assume this is the same as—or will automatically produce—flexibility in the second sense: adaptive, successful, or contextually appropriate behavior. Post-Standard Model psychology rests on the recognition that flexibility in this second sense is not something that is teleologically inevitable once constraints are removed, but is, instead, something very improbable and difficult to achieve, requiring elaborate functionally organized machinery.

The Weakness of Content-Independent Architectures

> If the doors of perception were cleansed everything would appear to man as it is, infinite.
>
> —WILLIAM BLAKE

If plasticity by itself is not only useless but injurious, the issue then becomes, what kind of guidance systems can propel computational systems sufficiently often toward the small scattered islands of successful outcomes in the endless expanse of alternative possibilities? Attempts over the last three decades to answer this question have led directly to two related concepts, called by artificial intelligence researchers and other cognitive scientists *combinatorial explosion* and the *frame problem.*

Combinatorial explosion is the term for the fact that with each new degree of freedom added to a system, or with each new dimension of potential variation added, or with each new successive choice in a chain of decisions, the total number of alternative possibilities faced by a computational system grows with devastating rapidity. For example, if you are limited to emitting only one out of 100 alternative behaviors every successive minute (surely a gross underestimate: raise arm, close hand, toss book, extend foot, say "Havel," etc.), after the second minute you have 10,000 different behavioral sequences from which to choose, a million by the third minute, a trillion by six minutes, and 10^{120} possible alternative sequences after only one hour—a truly unimaginable number. Every hour, each human is surrounded by a new and endless expanse of behavioral possibility. Which leads to the best outcome? Or, leaving aside optimality as a hopelessly utopian luxury in an era of diminished expectations, which sequences are nonfatal? The system could not possibly compute the anticipated outcome of each alternative and compare the results, and so must be precluding without complete consideration the overwhelming majority of branching pathways. What are the principles that allow us to act better than randomly?

Combinatorial explosion attacks any system that deals with alternatives, which means any system that is flexible in response or has decisions to make. The more flexible the system, the greater the problem. Even worse, knowledge acquisition is impossible for a computational system equipped only with the limited information it can gain through its senses; this is because the number of alternative states of affairs in the world that are consistent with its sense data is infinite. For example, if cognitive mechanisms are attempting to infer the meaning of an unknown word, there is an infinite set of potential meanings. If perceptual mechanisms are trying to construct a three dimensional model of the local world from a visual array, there is an infinite number of different ways to do it that are all consistent with the array. For any finite sample of sentences encountered, there exists an infinite number of alternative grammars that could have generated them. If one is making a decision about how to forage there is, practically speaking, an infinite number of possibilities. Moreover, random choice is not a general solution to the problem because for most adaptive or humanly defined problems the islands of success are infinitesimal next to the illimitable seascapes of failure. And for biological systems, success and failure are not arbitrary. The causal world imposes a nonarbitrary distinction between detecting in one's visual array the faint outline of a partly camouflaged stalking predator and not detecting it because of alternative interpretive procedures. Nonpropagating designs are removed from the population, whether they believe in naive realism or that everything is an arbitrary social construction.

The inexhaustible range of possibilities latent in behavior, categorization, interpretation, decision, and so on, is a not just an abstract philosophical point. It is an implacable reality facing every problem-solving computational system. Each prelinguistic child trying to learn her own language or to induce new knowledge about the world is faced with this problem; so is every artificial intelligence system. In artificial intelligence research, it is called the "frame problem" (Boden, 1977); in linguistics, this problem is called the "poverty of the stimuli" (Chomsky, 1975); in semantics, it is called the problem of "referential ambiguity" (Gleitman & Wanner, 1982); in developmental psychology, it is called the "need for constraints on induction" (Carey, 1985a); in perception, they say that the stimulus array "underdetermines" the interpretation. Any design for an organism that cannot generate appropriate decisions, inferences, or perceptions because it is lost in an ocean of erroneous possibilities will not propagate, and will be removed from the population in the next generation. As selection pressures, combinatorial explosion and the frame problem are at least as merciless as starvation, predation, and disease.

With this as background, the converging results from artificial intelligence, perception, cognitive development, linguistics, philosophy, and evolutionary biology about the weaknesses of domain-general content-independent mechanisms are not difficult to fathom. One source of difficulty can be sketched out quickly. If a computational system, living or electronic, does not initially know the solution to the problem it faces then its procedures must operate to find a solution. What methods do content-independent systems bring to problem-solving? To describe a system as domain-general or content-independent is to say not what it is but only what it lacks: It lacks any specific a priori knowledge about the recurrent structure of particular situations or problem-domains, either in declarative or procedural form, that might guide the system to a solution quickly. It lacks procedures that are specialized to detect and deal with particular kinds of problems, situations, relationships, or contents in ways that differ from any other kind of problem, situation, relationship, or content. By definition, a domain-general system takes a "one size fits all" approach.

To understand the importance of this, consider the definition of an adaptation. An *adaptation* is a reliably developing structure in the organism, which, because it meshes with the recurrent structure of the world, causes the solution to an adaptive problem. It is easy to see how a specific structure, like a bug detector in a frog's retina, in interaction with bug trajectories in the local environment, solves a feeding problem for the frog. It is easy to see how the Westermarck sexual disinterest mechanism combines with the co-residence cue to diminish the probability of sex between close relatives (Shepher, 1983; Wolf & Huang, 1980). When the class of situations that a mechanism is designed to solve is more narrowly defined, then (1) the situations will have more recurrent features in common, and therefore (2) the mechanism can "know" more in advance about any particular situation that is a member of this class. As a result, (3) the mechanism's components can embody a greater variety of problem-solving strategies. This is because mechanisms work by meshing with the features of situations and, by definition, narrowly defined situations have more features in common. Our depth perception mechanism has this property, for example: It works well because it combines the output of many small modules, each sensitive to a different cue correlated with depth. In addition, (4) the narrower the class, the more likely it is that a good, simple solution exists—a solution that does not require the simultaneous presence of many common features. The frog can have a simple "bug detector" precisely because insects share features with one another that are not shared by many members of more inclusive classes, such as "animals" or "objects."

In contrast, the more general a problem-solving technique is, the larger the range of situations across which the procedure must successfully apply itself. When the class of situations that a mechanism must operate over is more broadly defined, then (1) the situations will have fewer recurrent features in common, therefore (2) the mechanism can "know" less in advance about any particular situation that is a member of this class. Because (3) broadly defined situations have so few features in common for a mechanism to mesh with, there exist fewer strategies capable of solving the problem.

This result is logically inevitable. Every kind of problem-solving strategy that applies to a more inclusive class also applies to every subset within it; but not every strategy that applies to a narrowly defined class will apply to the larger classes that contain it (e.g., all insects are objects, but not all objects are insects). By identifying smaller and smaller problem domains on the basis of an increasing set of recurrent similarities, more and more problem-solving strategies can be brought to bear on that set. Conversely, by widening the problem domain that a mechanism must address, strategies that worked correctly on only a subset of problems must be abandoned or subtracted from the repertoire because they give incorrect answers on the newly included problems in the enlarged domain. As problem domains get larger and more broadly defined, a smaller and smaller set of residual strategies is left that remains applicable to the increasingly diverse set of problems. At the limit of perfect generality, a problem-solving system can know nothing except that which is always true of every situation in any conceivable universe and, therefore, can apply no techniques except those that are applicable to all imaginable situations. In short, it has abandoned virtually anything that could lead it to a solution.

This weakness of domain-general architectures arises not because all relatively general problem-solving techniques are useless; indeed, many are very useful—the ability to reject propositions because they are contradicted, the ability to associate, and the ability to recalibrate based on the consequences of actions, for example. The weakness arises because content-sensitivity and specialization are eliminated from the architecture. By definition, a content-independent architecture does not distinguish between different problem-domains or content classes; therefore, it is restricted to employing only general principles of problem-solving that can apply to all problems.

In contrast, a content-dependent domain-specific architecture does identify situations as members of specific problem domains and content classes. Because of this, it can maintain a repertoire of specialized problem-solving techniques that are only activated when they encounter the delimited domains to which they are applicable (e.g., snakes, sex with kin, grammar, falling in love, faces). At the same time, a pluralistic architecture can simultaneously activate every other problem-solving technique appropriate to the larger and more inclusive classes that contain the problem encountered (for faces: face recognition, object recognition, association formation, and so on). Thus, a domain-specific architecture can deploy every general problem-solving technique at the disposal of a domain-general architecture and a multitude of more specific ones as well. This sensible approach to organizing a problem-solving architecture is exactly what is ruled out by SSSM advocates of a content-independent mind whose procedures operate uniformly over every problem or domain.

To put it in adaptationist terms, what does the work of adaptive problem-solving for organisms is (1) the recurrent structure of the world relevant to the problem, in interaction with (2) the recurrent structure of the adaptation. The more broadly defined the problem domain is (1) the less recurrent structure can be supplied by the world (because more diverse situations have less recurrent structure in common), and (2) the less recurrent structure can be supplied by the adaptation in the form of problem-solving procedures that are solution-promoting across a diverse class of situations. The erosion of both sets of problem-solving structures—those in the adaptation and those in the world—increasingly incapacitates the system. This can sometimes be compensated for, but only through a correspondingly costly increase in the amount of computation used in the attempt to solve the problem. The less the system knows about the problem or the world to begin with, the more possibilities it must contend with. Permutations being what they are, alternatives increase exponentially as generality increases and combinatorial explosion rapidly cripples the system. A mechanism unaided by domain-specific rules of relevance, specialized procedures, "preferred" hypotheses, and so on could not solve any biological problem of routine complexity in the amount of time the organism has to solve it, and usually could not solve it at all.

It is the perennial hope of SSSM advocates within the psychological community that some new technology or architecture (wax impressions, telephone switching, digital computers, symbol-processing, recursive programming languages, holograms, non-von Neumann architectures, parallel-distributed processing—a new candidate emerges every decade or so), will free them to return to empiricism, associationism, domain-generality and content-independence (where the SSSM tells them they should go). Nevertheless, the functional necessity of content-specificity emerges in every technology because it is a logical inevitability. Most recently, researchers are establishing this all over again with connectionism (e.g., Jacobs, Jordan, & Barto, 1990; Miller &

Todd, 1990; Pinker & Prince, 1988; Todd & Miller, 1991a, 1991b). Combinatorial explosion and the frame problem are obstacles that can only be overcome by endowing computational architectures with contentful structure. This is because the world itself provides no framework that can decide among the infinite number of potential category dimensions, the infinite number of relations, and the infinite number of potential hypotheses that could be used to analyze it.

The Necessity of Frames

Artificial intelligence research is particularly illuminating about these issues because explicitness is demanded in the act of implementing as programs specific hypotheses about how problems can be solved. By the program's operation, one can tell a great deal about the adequacy of the hypothesis. Moreover, artificial intelligence researchers became interested in getting computers and robots to perform real world tasks, where, just as in evolutionary biology, action is taken in a real, structured, and consequential environment. As a result, artificial intelligence researchers can tell unambiguously whether the decisions the system makes are a success or a failure. The range of problems studied in artificial intelligence widened beyond cognitive psychology's more traditional, philosophy-derived concerns, to include problems such as the regulation of purposive action in a three-dimensional world.

To their great surprise, artificial intelligence researchers found that it was very difficult to discover methods that would solve problems that humans find easy, such as seeing, moving objects or even tying shoelaces. To get their programs to handle even absurdly simplified tasks (such as moving a few blocks around), they were forced to build in substantial "innate knowledge" of the world. As a practical matter, this "knowledge" was either in the form of (1) content-dependent procedures matched closely to the structural features of the task domain within which they were designed to operate, or (2) representations (data structures) that accurately reflected the task domain (i.e., "knowledge of the world"). To move an object, make the simplest induction, or solve a straightforward problem, the computer needed a sophisticated model of the domain in question, embodied either in procedures or representations. Artificial intelligence research demonstrated in a concrete, empirical form, the long-standing philosophical objections to the tabula rasa (e.g., Hume, 1977/1748; Kant, 1966/1781; Popper, 1972; Quine, 1960, 1969). These demonstrations have the added advantage of bracketing just how much "innate" structure is necessary to allow learning to occur.

Artificial intelligence researchers call the specific contentful structures that problem-solving systems need to be endowed with *frames*. For this reason, the consistent inability of systems without sufficiently rich and specialized frames to solve real problems is called the *frame problem* (e.g., Boden, 1977; F. M. Brown, 1987; Fodor, 1983). A frame provides a "world-view": It carves the world into defined categories of entities and properties, defines how these categories are related to each other, suggests operations that might be performed, defines what goal is to be achieved, provides methods for interpreting observations in terms of the problem space and other knowledge, provides criteria to discriminate success from failure, suggests what information is lacking and how to get it, and so on. For example, one might apply a spatial/object frame to a situation. In such a frame, the local world is carved into empty space and objects, which are cohesive, have boundaries defined by surfaces, and move as a unit. They have locations and orientations with respect to each other. They have trajectories and, if solid, cannot pass through one another (unless they change the shape of the object passed through), and so on. In such a framing, humans are simply objects like any other and are not expected to pass through other solid objects. Alternatively, one might have a coalitional framing (present, for example, in a football game or a war), in which humans are a relevant and differentiated entity and are construed as animate goal-seeking systems that are members of one of two mutually exclusive social sets; the members of each set are expected to coordinate their behavior with each other to reach goals that cannot be mutually realized for both sets; the goal of each set is to thwart the purposes of the other, and so on. In our own work, we have attempted to sketch out some of the framing necessary for humans to engage in social exchange (Cosmides, 1989; Cosmides & Tooby, 1989, this volume). Very general mechanisms have frames as well: In the formal logic of the propositional calculus, the problem-space is defined syntactically in terms of sets of propositions, truth values, and rules of inference such as *modens ponens* and *modus tollens*. In this frame, the content of the propositions is irrelevant to the operation of the rules of inference.

The solution to the frame problem and combinatorial explosion is always the same whether one is talking about an evolved organism or an artificial intelligence system. When the information available from the world is not sufficient to allow learning to occur or the problem to be solved, it must be supplied from somewhere else. Because the world cannot supply to the system what the system needs first in order to learn about the world, the essential kernals of content-specific framing must be supplied initially by the architecture. For an artificial intelligence system, a programmer can supply it. For organisms, however, it can only be supplied through the process of natural selection, which creates reliably developing architectures that come equipped with the right frames and frame-builders necessary to solve the adaptive problems the species faced during its evolutionary history.

Because of their survival into the present, we know for a fact that living species can reliably solve an enormous array of problems necessary to consistently reproduce across thousands of generations in natural environments. Moreover, the signal lesson of modern evolutionary biology is that this adaptive behavior requires the solution of many information-processing problems that are highly complex—far more complex than is commonly supposed (Cosmides & Tooby, 1987, 1989). If one bothers to analyze virtually any adaptive problem human hunter-gatherers solve, it turns out to require an incredible amount of evolved specialization (see, e.g, Cosmides & Tooby, 1989, this volume). Given (1) the complexity of the world, (2) the complexity of the total array of adaptive tasks faced by living organisms, and (3) the sensitive frame-dependence of problem-solving abilities, the psychological architecture of any real species must be permeated with domain-specific structure to cause reliable reproduction in natural environments. Current research in cognitive psychology and artificial intelligence indicates that Standard Model theories are far too frame-impoverished to solve even artificially simplified computational problems (e.g., identifying and picking up soda cans in the MIT artificial intelligence laboratory), let alone the complex information-processing problems regularly imposed by selective forces operating over evolutionary time.

Our minds are always automatically applying a rich variety of frames to guide us through the world. Implicitly, these frames appear to us to be part of the world. For precisely this reason, we have difficulty appreciating the magnitude, or even the existence of, the frame problem. Just as the effortlessness of seeing led artificial intelligence researchers to underestimate the complexity of the visual system, the automatic and effortless way in which our minds frame the world blinds us to the computational complexity of the mechanisms responsible. When anthropologists go to other cultures, the experience of variation awakens them to things they had previously taken for granted in their own culture. Similarly, biologists and artificial intelligence researchers are "anthropologists" who travel to places where minds are far stranger than anywhere any ethnographer has ever gone. We cannot understand what it is to be human until we learn to appreciate how truly different nonhuman minds can be, and our best points of comparison are the minds of other species and electronic minds. Such comparisons awaken us to an entire class of problems and issues that would escape us if we were to remain "ethnocentrically" focused on humans, imprisoned by mistaking our mentally imposed frames for an exhaustive demarcation of reality.

When we examine electronic minds that truly have no frames and then try to give them even a few of our own real world capacities, we are made forcefully aware of the existence of the immensely intricate set of panhuman frames that humans depend on to function in the world, to communicate with one another, and to acquire additional frames through social inference from others (i.e., to "learn culture"). Geertz's (1973) studies in Bali acquainted him with some of the culturally variable frames that differ between Bali and the United States, but, as his writings make clear, they left him oblivious to the encompassing, panhuman frames within which these variable elements were embedded (D. E. Brown, 1991). If he had widened his scope to include other animal species, he would have been made strongly aware of this dense level of universal and human-specific metacultural frames—a level that should interest every anthropologist because it permeates and structures every aspect of human life. Indeed, if Geertz had widened his scope still further to include electronic minds as points of comparison, he might have come to realize the sheer magnitude of what must be supplied by evolution to our psychological architectures for us to be recognizably human. Perhaps he might also have come to recognize that he and the "simple" Balinese fighting cocks he watched even shared many frames lacking from artificial intelligence systems (about things such as space, motion, vision, looming threats, pain, hunger, and, perhaps, conflict, rivalry, and status changes after fights). Biology, cognitive psychology, and artificial intelligence research comprise a new form of ethnography, which is revealing the previously invisible wealth of evolved frames and specialized frame-builders that our evolved psychological architecture comes equipped with.

The Evolvability Criterion and Standard Model Architectures

In a solvability analysis, the researcher asks whether a proposed architecture is capable of generating a behavior that we know humans (or the relevant species) regularly engage in, whether adaptive or not. But one can also evaluate a proposed architecture by asking how it would fare in solving the actual adaptive problems a species is known to have regularly confronted and solved during its evolutionary history. Because nonhuman and human minds—i.e., the computational systems responsible for regulating behavior—were produced by the evolutionary process operating over vast expanses of time, tenable hypotheses about their design must be drawn from the class of designs that evolution could plausibly—or at least possibly—have produced. To be adequate, proposed designs must be able to account for the solution of the broad array of distinct problems inherent in reliable reproduction over thousands of generations under ancestral conditions. In short, a candidate design must satisfy the *evolvability criterion*. In essence, designs that are more plausible according to criteria drawn from evolutionary biology are to be preferred over designs that are less plausible.

Some rules for evaluating hypotheses by the evolvability criterion are as follows:

1. Obviously, at a minimum, a candidate architecture must be able to perform all of the tasks and subtasks necessary for it to reproduce. It can have no properties that preclude, or make improbable, its own reproduction across multiple generations in natural environments. Just by itself, this is a difficult criterion to meet. No known Standard Model psychological architecture can solve all or even very many of the problems posed by reproduction in natural environments.

2. Given that human minds evolved out of prehuman primate minds, a hypothesis should not entail that an architecture that is substantially inferior at promoting its own propagation (its inclusive fitness) replace an architecture that was better designed to promote fitness under ancestral conditions. There is now known to be an entire range of competences and specialized design features that enhance propagation in a large array of other species. A candidate architecture should be at least roughly comparable to them in their ability to solve the classes of adaptive problems humans and other primate species mutually faced. For this reason, it is not sufficient to incorporate into a general-purpose system a few drives that account for why the organism does not die of thirst or hunger in a few days. Even though some psychological architectures of this kind might conceivably manage their own reproduction under artificially protected circumstances, they contain nothing that would solve other obvious propagation-promoting tasks that have called forth adaptive specializations in innumerable other species. Thus, to be plausible, a proposed human architecture should cause individuals to help relatives more or less appropriately, to defend sexual access to their mates, to forage in a relatively efficient way, and so on. The SSSM view that human evolution was a process of erasing "instincts" violates the evolvability criterion unless it can be shown that for each putatively "erased" adaptive specialization, the general-purpose mechanism that is proposed to have replaced it would have solved the adaptive problem better (Tooby, 1985; Tooby & DeVore, 1987). To our knowledge, no general mechanism operating under natural circumstances has ever been demonstrated to be superior to an existing adaptive specialization.

3. A candidate architecture should not require the world to be other than it really is. For example, models of grammar acquisition that assume that adults standardly correct their children's grammatical errors do not meet this condition (Pinker, 1989). Nor do socialization models that require children to be taught where their own interests lie by individuals with conflicting interests—for many domains, this class even includes the child's own parents and siblings (e.g., Hamilton, 1964; Trivers, 1974). An architecture that was completely open to manipulation by others, without any tendency whatsoever to modify or resist exploitive or damaging social input would be strongly selected against. For this reason, cognitive architectures that are passive vehicles for arbitrary semiotic systems are not plausible products of the evolutionary process.

4. In a related vein, a candidate theory should not invoke hypotheses that require assumptions about the coordinated actions of others (or any part of the environment) unless it explains how such coordination reliably came about during Pleistocene hunter-gatherer life. For example, if the model proposes that people acquire certain adaptive skills or information from others through, say, imitation or conversation,

that model needs to explain how these others reliably obtained the (correct) information and where the information originated. If the blind lead the blind, there is no advantage to imitation. Consequently, acceptable models should not employ shell games, such as the venerable "adaptive knowledge comes from the social world."

5. A candidate model must not propose the existence of complex capacities in the human psychological architecture unless these capacities solve or solved adaptive (design-propagative) problems for the individual. That is, social scientists should be extremely uneasy about positing an improbably complex structure in the system with the capacity to serve nonbiological functional ends, unless that capacity is a by-product of functionality that evolved to serve adaptive ends. Selection builds adaptive functional organization; chance almost never builds complex functional organization. So positing complex designs that serve the larger social good, or that complexly manipulate symbolic codes to spin webs of meaning, or that cause one to maximize monetary profit, all violate the evolvability criterion unless it can be shown that these are side effects of what would have been adaptive functional organization in the Pleistocene. Similarly, one should not posit the existence of complex functional designs that evolved to solve adaptive problems that emerged only very recently. Complex functionality requires time to evolve and, therefore, can arise only in response to long-standing adaptive problems (Dawkins, 1982, 1986; Tooby & Cosmides, 1990a).

Over the course of their evolution, humans regularly needed to recognize objects, avoid predators, avoid incest, avoid teratogens when pregnant, repair nutritional deficiencies by dietary modification, judge distance, identify plant foods, capture animals, acquire grammar, attend to alarm cries, detect when their children needed assistance, be motivated to make that assistance, avoid contagious disease, acquire a lexicon, be motivated to nurse, select conspecifics as mates, select mates of the opposite sex, select mates of high reproductive value, induce potential mates to choose them, choose productive activities, balance when walking, avoid being bitten by venomous snakes, understand and make tools, avoid needlessly enraging others, interpret social situations correctly, help relatives, decide which foraging efforts have repaid the energy expenditure, perform anticipatory motion computation, inhibit one's mate from conceiving children by another, deter aggression, maintain friendships, navigate, recognize faces, recognize emotions, cooperate, and make effective trade-offs among many of these activities, along with a host of other tasks. To be a viable hypothesis about human psychological architecture, the design proposed must be able to meet both solvability and evolvability criteria: It must be able to solve the problems that we observe modern humans routinely solving and it must solve all the problems that were necessary for humans to survive and reproduce in ancestral environments. No existing version of Standard Model psychology can remotely begin to explain how humans perform these tasks.

Over the course of this chapter, we have touched on how domain-specific mechanisms are empirically better supported than domain-general mechanisms, on why domain-general mechanisms cannot give rise to routinely observable behavioral performances, on why domain-specific architectures are usually more functional than domain-general architectures, and, especially, on why it is implausible or impossible for predominantly content-independent, domain-general computational systems to perform the tasks necessary for survival and reproduction in natural environments. The main arguments that we have reviewed here (and elsewhere; see Cosmides & Tooby, 1987, 1992; Tooby & Cosmides, 1990b) are as follows:

1. In order to perform tasks successfully more often than chance, the architecture must be able to discriminate successful performance from unsuccessful performance. Because a domain-general architecture by definition has no built-in content-specific rules for judging what counts as error and success on different tasks, it must have a general rule. Unfortunately, there is no useable general cue or criterion for success or failure that can apply across domains. What counts as good performance for one task (e.g., depth perception) is completely different from what counts as good performance for other tasks (e.g., incest avoidance, immune regulation, avoiding contagion, imitating, eating). The only unifying element in discriminating success from failure is whether an act promotes fitness (design-propagation). But the relative fitness contribution of a given decision cannot be used as a criterion for learning or making choices because it is inherently unobservable by the individual (for discussion, see Cosmides & Tooby, 1987, 1992; Tooby & Cosmides, 1990b). Consequently, our evolved psychological architecture needs substantial built-in content-specific structure to discriminate adaptive success from failure. There needs to be at least as many different domain-specific psychological adaptations as there are evolutionarily recurrent functional tasks with different criteria for success.

2. As discussed at length, domain-general, content-independent mechanisms are inefficient, handicapped, or inert compared to systems that also include specialized techniques for solving particular families of adaptive problems. A specialized mechanism can make use of the enduring relationships present in the problem-domain or in the related features of the world by reflecting these content-specific relationships in its problem-solving structure. Such mechanisms will be far more efficient than general-purpose mechanisms, which must expend time, energy, and risk learning these relationships through "trial and possibly fatal error" (Shepard, 1987a).

3. Many problems that humans routinely solve are simply not solvable by any known general problem-solving strategy, as demonstrated by formal solvability analyses on language acquisition (e.g., Pinker, 1979, 1984, 1989, 1991; Pinker & Prince, 1988). We think that the class of such problems is large and, as discussed above, includes at a minimum all motivational problems.

4. Different adaptive problems are often incommensurate. They cannot, in principle, be solved by the same mechanism (Chomsky, 1980). To take a simple example, the factors that make a food nutritious are different from those that make a human a good mate or a savannah a good habitat. As Sherry and Schacter point out, "functional incompatibility exists when an adaptation that serves one function cannot, because of its specialized nature, effectively serve other functions. The specific properties of the adaptation that make it effective as a solution to one problem also render it incompatible with the demands of other problems" (1987, p. 439).

5. Many adaptive courses of action can be neither deduced nor learned by general criteria alone because they depend on statistical relationships that are unobservable to the relevant individual. For a content-independent system to learn a relationship, all parts of the relationship must be perceptually detectable. This is frequently not the case. Natural selection can "observe" relationships that exist between a sensory cue, a decision rule, and a fitness outcome that is inherently unobservable to the individual making the decision (Tooby & Cosmides, 1990b), as in the case of pregnancy sickness (Profet, 1988, this volume) or the Westermarck incest avoidance mechanism (Shepher, 1983; Wolf & Huang, 1980). This is because natural selection does not work by inference or computation: It took the real problem, "ran the experiment," and

retained those designs whose information-processing procedures led over thousands of generations to the best outcome. Natural selection, through incorporating content-specific decision rules, allows the organism to behave as if it could see and be guided by relationships that are perceptually undetectable and, hence, inherently unlearnable by any general-purpose system.

6. As discussed, the more generally framed problems are, the more computational systems suffer from combinatorial explosion, in which proliferating alternatives choke decision and learning procedures, bringing the system to a halt. If it were true that, as Rindos (1986, p. 315) puts the central tenet of the Standard Social Science Model, "the specifics that we learn are in no sense predetermined by our genes," then we could learn nothing at all.

7. Everything a domain-general system can do can be done as well or better by a system that also permits domain-specific mechanisms because selection can incorporate any successful domain-general strategies into an architecture without displacing its existing repertoire of domain-specific problem-solvers.

Without further belaboring the point, there is a host of other reasons why content-free, general-purpose systems could not evolve, could not manage their own reproduction, and would be grossly inefficient and easily outcompeted if they did. Equally important, these arguments apply not simply to the extreme limiting case of a completely content-free, domain-general architecture but to all Standard Model architectures, as conventionally presented. The single criterion that any proposed human psychological architecture must solve all the problems necessary to cause reliable reproduction under natural conditions is decisive. When taken seriously and considered carefully, it leads to the conclusion that the human psychological architecture must be far more frame-rich and permeated with content-specific structure than most researchers (including ourselves) had ever suspected.

The Content-Specific Road to Adaptive Flexibility

The ability to adjust behavior flexibly and appropriately to meet the shifting demands of immediate circumstances would, of course, be favored by selection, other things being equal. What organism would not be better off if it could solve a broader array of problems? Moreover, the psychologies of different species do differ in the breadth of situations to which they can respond appropriately, with humans acting flexibly to a degree that is zoologically unprecedented. Humans engage in elaborate improvised behaviors, from composing symphonies to piloting aircraft to rice cultivation, which collectively indicate a generality of achieved problem-solving that is truly breathtaking. Although many human acts do not successfully solve adaptive problems, enough do that the human population has increased a thousandfold in only a few thousand years. If general-purpose mechanisms are so weak, how can the variability of observed human behavior be reconciled with its level of functionality?

As discussed above, there is little in content-independent, domain-general strategies of problem-solving that by themselves can account for functional behavior, whether it is flexible or not. In contrast, specialized mechanisms can be very successful and powerful problem-solvers, but they achieve this at the price of addressing a narrower range of problems than a more general mechanism. If these were the only two alternatives, organisms would be limited to being narrow successes or broad failures, and the human case of broad adaptive flexibility could not be accounted for.

The solution to the paradox of how to create an architecture that is at the same time both powerful and more general is to bundle larger numbers of specialized mechanisms together so that in aggregate, rather than individually, they address a larger range of problems. Breadth is achieved not by abandoning domain-specific techniques but by adding more of them to the system. By adding together a face recognition module, a spatial relations module, a rigid object mechanics module, a tool-use module, a fear module, a social-exchange module, an emotion-perception module, a kin-oriented motivation module, an effort allocation and recalibration module, a child-care module, a social-inference module, a sexual-attraction module, a semantic-inference module, a friendship module, a grammar acquisition module, a communication-pragmatics module, a theory of mind module, and so on, an architecture gains a breadth of competences that allows it to solve a wider and wider array of problems, coming to resemble, more and more, a human mind. The more a system initially "knows" about the world and its persistent characteristics, and the more evolutionarily proven "skills" it starts out with, the more it can learn, the more problems it can solve, the more it can accomplish. In sharp contrast to the Standard Model, which views an absence of content-specific structure as a precondition for richly flexible behavior, the analysis of what computational systems actually need to succeed suggests the opposite: that the human capacity for adaptive flexibility and powerful problem-solving is so great precisely because of the number and the domain-specificity of the mechanisms we have. Again, this converges on William James's argument that humans have more "instincts" than other animals, not fewer (James, 1892; Symons, 1987).

Moreover, there are many reasons to think that the number of function-general mechanisms and function-specific mechanisms in an architecture are not inversely related in a zero-sum relationship, but are positively related (Rozin, 1976). Content-specialized mechanisms dissect situations, thereby creating a problem space rich with relevant relationships that content-independent mechanisms can exploit (e.g., Cosmides & Tooby, under review; Gigerenzer, Hoffrage & Kleinbölting, 1991; Shepard, 1987b). Thus, the more alternative content-specialized mechanisms an architecture contains, the more easily domain-general mechanisms can be applied to the problem spaces they create without being paralyzed by combinatorial explosion. Although domain-general mechanisms may be weak in isolation, they can valuably broaden the problem-solving range of an architecture if they are embedded in a matrix of adaptive specializations that can act as a guidance system (Rozin, 1976). For example, humans have powerful specialized social inference mechanisms that reflect the contentful structure of human metaculture, allowing humans to evaluate and interpret others' behaviors. This provides a foundation for the human-specific ability to imitate others (Galef, 1988; Meltzoff, 1988), greatly increasing the range of situations to which they can respond appropriately.

Therefore, what is special about the human mind is not that it gave up "instinct" in order to become flexible, but that it proliferated "instincts"—that is, content-specific problem-solving specializations—which allowed an expanding role for psychological mechanisms that are (relatively) more function-general. These are presently lumped into categories with unilluminating labels such as "the capacity for culture," "intelligence," "learning," and "rationality." It is time for the social sciences to turn from a nearly exclusive focus on these embedded, more function-general mechanisms to a wider view that includes the crucial, and largely neglected, superstructure of evolved functional specializations. Equally, we need to explore how the two classes of mechanisms are interwoven so that their combined interactive product is the zoologically unique yet evolutionarily patterned breadth of functional behaviors.

EVOLUTIONARY PSYCHOLOGY AND THE GENERATION OF CULTURE

The Pluralistic Analysis of Human Culture and Mental Organization

> Malinowski maintained that cultural facts are partly to be explained in psychological terms. This view has often been met with skepticism or even scorn, as if it were an easily exposed naive fallacy. What I find fallacious are the arguments usually leveled against this view. What I find naive is the belief that human mental abilities make culture possible and yet do not in any way determine its content and organization.
>
> —DAN SPERBER (1985, p. 73)

A large and rapidly growing body of research from a diversity of disciplines has shown that the content-independent psychology that provides the foundation for the Standard Social Science Model is an impossible psychology. It could not have evolved; it requires an incoherent developmental biology; it cannot account for the observed problem-solving abilities of humans or the functional dimension of human behavior; it cannot explain the recurrent patterns and characteristic contents of human mental life and behavior; it has repeatedly been empirically falsified; and it cannot even explain how humans learn their culture or their language. With the failure of Standard Model psychology, and the emergence of a domain-specific psychology, the remaining logic of the Standard Social Science Model also collapses.

In this chapter, we have limited ourselves to analyzing some of the defects of the Standard Social Science Model, concentrating on the untenability of the psychology that forms the foundation for its theory of culture. Along the way, we have touched on only a handful of the changes that an evolutionary psychological approach would introduce into the theoretical foundations of the social sciences. These and the remarks that follow should not, however, be mistaken for a substantive discussion of what a new theory of culture that was based on modern biology, psychology, and anthropology would look like. Still less should they be mistaken for a presentation of the mutually consistent conceptual framework (what we have been calling the Integrated Causal Model) that emerges when the various biological, behavioral, and social science fields are even partially integrated and reconciled. Because our argument has been narrowly focused on psychology, we have been unable to review or discuss the many critical contributions that have been made to this embryonic synthesis from evolutionary biology, anthropology, neurobiology, sociology, and many other fields. These must be taken up elsewhere. In particular, readers should be aware that the ideas underlying the Integrated Causal Model are not original with us: They are the collaborative product of hundreds of individual scholars working in a diverse array of fields over the last several decades.[7] Indeed, the collaborative dimension of this new framework is key. The eclipse of the Standard Model and the gradual emergence of its replacement has resulted from researchers exploring the natural causal connections that integrate separate fields (see, e.g., Barkow, 1989, on the importance of making psychology consistent with biology and anthropology consistent with psychology). The research program we and others are advocating is one of integration and consistency, not of psychological or biological reductionism. (See Atran, 1990; Daly & Wilson, 1988; and Symons, 1979, for examples of how such integrative approaches can be applied to specific problems.)

What does the rise of domain-specific psychology mean for theories of culture? By themselves, psychological theories do not and cannot constitute theories of culture. They only provide the foundations for theories of culture. Humans live and evolved in interacting networks that exhibit complex population-level dynamics, and so theories and analyses of population-level processes are necessary components for any full understanding of human phenomena. Nevertheless, increasing knowledge about our evolved psychological architecture places increasing constraints on admissible theories of culture. Although our knowledge is still very rudimentary, it is already clear that future theories of culture will differ significantly in a series of ways from Standard Social Science Model theories. Most fundamentally, if each human embodies an evolved psychological architecture that comes richly equipped with content-imparting mechanisms, then the traditional concept of culture itself must be completely rethought.

Culture has been the central concept of the Standard Social Science Model. According to its tenets, culture is a unitary entity that expresses itself in a trinity of aspects. (1) It is conceived as being some kind of contingently variable informational substance that is transmitted by one generation to another within a group: Culture is what is socially learned. (2) Because the individual mind is considered to be primarily a social product formed out of the rudimentary infant mind, all or nearly all adult mental organization and content is assumed to be cultural in derivation and substance: Culture is what is contentful and organized in human mental life and behavior. (3) Humans everywhere show striking patterns of local within-group similarity in their behavior and thought, accompanied by significant intergroup differences. The existence of separate streams of transmitted informational substance is held to be the explanation for these group patterns: Cultures are these sets of similarities, and intergroup or cross-location differences are called cultural differences.

In the absence of a content-free psychology, however, this trinity breaks into separate pieces because these three sets of phenomena can no longer be equated. We have already sketched out why the human mind must be permeated with content and organization that does not originate in the social world. This breaks apart any simple equivalence between the first two meanings of "culture." Nevertheless, even for those who admit that the mind has some content that is not socially supplied, the distribution of human within-group similarities and between-group differences remains the most persuasive element in the Standard Model analysis. These salient differences are taken to confirm that the socially learned supplies most of the rich substance of human life (see "The Standard Social Science Model", pp. 24–34). Because Standard Model advocates believe that a constant—our universal evolved architecture—cannot explain what varies, they can see no explanation for "cultural differences" other than differences in transmitted information.

Although this conclusion seems compelling, a simple thought experiment illustrates why it is unfounded. Imagine that extraterrestrials replaced each human being on earth with a state-of-the-art compact disk juke box that has thousands of songs in its repertoire. Each juke box is identical. Moreover, each is equipped with a clock, an automated navigational device that measures its latitude and longitude, and a circuit that selects what song it will play on the basis of its location, the time, and the date.

What our extraterrestrials would observe would be the same kind of pattern of within-group similarities and between-group differences observable among humans: In Rio, every juke box would be playing the same song, which would be different from the song that every juke box was playing in Beijing, and so on, around the world. Each juke box's "behavior" would be clearly and complexly patterned because each had been equipped with the same large repertoire of songs. Moreover, each juke box's behavior would change over time, because the song it plays is a function of the date and time, as well as of its location. Juke boxes that were moved from location to location would appear to adopt the local songs, sequences, and "fashions." Yet the generation of this distinctive, culture-like pattern involves no social learning or transmission whatsoever. This pattern is brought about because, like humans, the juke boxes (1) share a universal, highly organized, architecture, that (2) is designed to respond to inputs from the local situation (e.g., date, time, and location).

All humans share a universal, highly organized architecture that is richly endowed with contentful mechanisms, and these mechanisms are designed to respond to thousands of inputs from local situations. As a result, humans in groups can be expected to express, in response to local conditions, a variety of organized within-group similarities that are not caused by social learning or transmission. Of course, these generated within-group similarities will simultaneously lead to systematic differences between groups facing different conditions. To take a single example, differences in attitudes toward sharing between hunter-gatherer groups may be evoked by ecological variables (for discussion, see Cosmides & Tooby, this volume).

Thus, complex shared patterns that differ from group to group may be evoked by circumstances or may be produced by differential transmission. For this reason, the general concept of "culture" in the Standard Model sense is a conflation of *evoked culture* and *transmitted culture* (as well as of metaculture and other components). Given that the mind contains many mechanisms, we expect that both transmitted and evoked factors will play complementary roles in the generation of differentiated local cultures. The operation of a richly responsive psychology, plus the ability to socially "learn," can jointly explain far more about "culture" and cultural change than either can alone. For example, when members of a group face new and challenging circumstances (drought, war, migration, abundance), this may activate a common set of functionally organized domain-specific mechanisms, evoking a new set of attitudes and goals. The newly evoked psychological states will make certain new ideas appealing, causing them to spread by transmission, and certain old ideas unappealing, causing them to be discarded. In contrast, the Standard Model "do what your parents did" concept of culture is not a principle that can explain much about why cultural elements change, where new ones come from, why they spread, or why certain complex patterns (e.g., pastoralist commonalities) recur in widely separated cultures. Of course, many anthropologists implicitly recognize these points, but they need to make the links between the cultural processes they study and the underlying evolved content-organizing psychology they are assuming explicit. For example, economic and ecological anthropology, to be coherent, necessarily assume underlying content-specialized psychological mechanisms that forge relationships between environmental and economic variables and human thought and action.

It is especially important for post-Standard Model researchers to recognize that the environmental factors that cause contentful mental and behavioral organization to be expressed are not necessarily the processes that constructed that organization. In the case of the juke box, it would be a mistake to attribute the organized content manifest in the music to the environmental stimuli (i.e., the location, date, and time) that caused one song to be played rather than another. The stimuli did not compose the music; they merely caused it to be expressed. Similarly, our psychological architectures come equipped with evolved contentful organization, which can remain latent or become activated depending on circumstances and which may vary in its expression according to procedures embodying any degree of complexity. Because our psychological architecture is complexly responsive, the Standard Model practice of equating the variable with the learned is a simple non sequitur. The claim that some phenomena are "socially constructed" only means that the social environment provided some of the inputs used by the psychological mechanisms of the individuals involved.

In short, observations of patterns of similarities and differences do not establish that the substance of human life is created by social learning. In any specific case, we need to map our evolved psychological architecture to know which elements (if any) are provided by transmission, which by the rest of the environment, which by the architecture, and how all these elements causally interact to produce the phenomenon in question. Admittedly, the juke box thought experiment is an unrealistically extreme case in which a complex, functionally organized, content-sensitive architecture internalizes no transmitted informational input other than an environmental trigger. But this case is simply the mirror image of the SSSM's extreme view of the human mind as a content-free architecture where everything is provided by the internalization of transmitted input. Our central point is that in any particular domain of human activity, the programming that gives our architecture its ability to contingently respond to the environment may or may not be designed to take transmitted representations as input. If it does, it may mix in content derived from its own structure and process the resulting representations in complex and transformative ways. The trinity of cultural phenomena can no longer be equated with one another. Our complex content-specific psychological architecture participates in the often distinct processes of generating mental content, generating local similarities and between-group differences, and generating what is "transmitted." Indeed, it also participates in the complex process of internalizing what others are "transmitting."

Inferential Reconstruction and Cultural Epidemiology

The Standard Social Science Model has been very effective in promulgating the unity of the trinity. The socially learned, the set of within-group commonalities and between-group differences, and the contentful organization of human mental and social life have been so thoroughly conflated that it is difficult to speak about human phenomena without using the word *culture.* For this reason, we will use *culture* to refer to any mental, behavioral, or material commonalities shared across individuals, from those that are shared across the entire species down to the limiting case of those shared only by a dyad, regardless of why these commonalities exist. When the causes of the commonality can be identified, we will use a qualifier, such as "evoked."

So things that are cultural in the sense of being organized, contentful, and shared among individuals may be explained in a number of different ways. Within-group commonalities may have been evoked by common circumstances impacting universal architectures. An even larger proportion of organized, contentful, and shared phenomena may be explained as the expression of our universal psychological and physiological architectures in interaction with the recurrent structure of the social or nonsocial world—what we earlier called metaculture. Metaculture includes a huge range of psychological and behavioral phenomena that under Standard Model analyses have been invisible or misclassified (D. E. Brown, 1991). Because the Standard Model attributed everything that was contentful and recurrent to some form of social learning, it misinterpreted phenomena such as anger upon deliberate injury, grief at a loss, the belief that others have minds, treating species as natural kinds, social cognition about reciprocation, or the search for food when hungry as socially manufactured products.

Nevertheless, after the evoked and the metacultural have been excluded, there still remains a large residual category of representations or regulatory elements that reappear in chains from individual to individual—"culture" in the classic sense. In giving up the Standard Social Science Model, we are not abandoning the classic concept of culture. Instead, we are attempting to explain what evolved psychological mechanisms cause it to exist. That way we can get a clearer causal understanding of how psychological mechanisms and populational processes shape its content, and thereby restrict its explanatory role in social theory to the phenomena that it actually causes.

This subset of cultural phenomena is restricted to (1) those representations or regulatory elements that exist originally in at least one mind that (2) come to exist in other minds because (3) observation and interaction between the source and the observer cause inferential mechanisms in the observer to recreate the representations or regulatory elements in his or her own psychological architecture. In this case, the representations and elements inferred are contingent: They could be otherwise and, in other human minds, they commonly are otherwise. Rather than calling this class of representations "transmitted" culture, we prefer terms such as *reconstructed culture*, *adopted culture*, or *epidemiological culture*. The use of the word "transmission" implies that the primary causal process is located in the individuals from whom the representations are derived. In contrast, an evolutionary psychological perspective emphasizes the primacy of the psychological mechanisms in the learner that, given observations of the social world, inferentially reconstruct some of the representations existing in the minds of the observed. Other people are usually just going about their business as they are observed, and are not necessarily intentionally "transmitting" anything.

More precisely, an observer (who, for expository simplicity, we will call the "child") witnesses some finite sample of behavior by others (e.g., public representations, such as utterances or other communicative acts; people going about their affairs; people responding to the child's behavior). The task of the mechanisms in the child is to (1) reconstruct within themselves on the basis of these observations a set of representations or regulatory elements that (2) are similar enough to those present in the humans she lives among so that (3) the behavior her mechanisms generate can be adaptively coordinated with other people and her habitat. Thus, the problem of learning "culture" lies in deducing the hidden representations and regulatory elements embedded in others' minds that are responsible for generating their behavior. To the extent that the child's mechanisms make mistakes—and mistakes are endemic—and reconstruct the wrong underlying representations and regulatory elements, she will not be able to predict other people's behavior, interpret their transactions with one another in the world, imitate them, communicate with them, cooperate with them, help them, or even anticipate or avoid their hostile and exploitive actions.

Why did ancestral hominid foragers evolve mechanisms that allowed them to reconstruct the representations present in the minds of those around them? Leaving aside the question of their costs and limitations, the advantage of such mechanisms is straightforward. Information about adaptive courses of action in local conditions is difficult and costly to obtain by individual experience alone. Those who have preceded an individual in a habitat and social environment have built up in their minds a rich store of useful information. The existence of such information in other minds selected for specialized psychological adaptations that were able to use social observations to reconstruct some of this information within one's own mind (e.g., Boyd & Richerson, 1985; Tooby & DeVore, 1987). By such inferential reconstruction, one individual was able to profit from deducing what another already knew. When such inferential reconstruction becomes common enough in a group, and some representations begin to be stably re-created in sequential chains of individuals across generations, then the structure of events begins to warrant being called "cultural."

As discussed earlier, this task of reconstruction would be unsolvable if the child did not come equipped with a rich battery of domain-specific inferential mechanisms, a faculty of social cognition, a large set of frames about humans and the world drawn from the common stock of human metaculture, and other specialized psychological adaptations designed to solve the problems involved in this task (see, e.g., Boyer, 1990; Sperber, 1985, 1990; Sperber & Wilson, 1986; Tooby & Cosmides, 1989a). Consequently, epidemiological culture is also shaped by the details of our evolved psychological organization. Thus, there is no radical discontinuity inherent in the evolution of "culture" that removes humans into an autonomous realm. Mechanisms designed for such inferential reconstruction evolved within a pre-existing complex psychological architecture and depended on this encompassing array of content-structuring mechanisms to successfully interpret observations, reconstruct representations, modify behavior, and so on. Solving these inferential problems is not computationally trivial, and other species, with a few possible minor exceptions, are not equipped to perform this task to any significant degree (Galef, 1988).

Moreover, outside of contexts of competition, knowledge is not usually devalued by being shared. Consequently, to the substantial extent that individuals in a hunter-gatherer group had interests in common and had already evolved mechanisms for inferential reconstruction, selection would have favored the evolution of mechanisms that facilitated others' inferences about one's own knowledge (as, for example, by communicating or teaching). The mutual sharing of valuable knowledge and discoveries has a dramatic effect on the usefulness of mechanisms that attempt to adaptively adjust behavior to match local conditions (Boyd & Richerson, 1985; Tooby & DeVore, 1987). Because of combinatorial explosion, knowledge of successful local techniques is precious and hard to discover, but relatively cheap to share (once again, ignoring the cost of the psychological mechanisms that facilitate or perform such sequential reconstruction). Within limits, this creates economies of scale: The greater the number of individuals who participate in the system of knowledge sharing, (1) the larger the available pool of knowledge will be, (2) the more each individual can derive from the pool, (3) the more advantageous reconstructive adaptations will be, and (4) the more it would pay to evolve knowledge-dependent mechanisms that could exploit this set of local representations to improvise solutions to local problems. This collaborative information-driven approach to the adaptive regulation of behavior can be thought of as the "cognitive niche" (Tooby & DeVore, 1987). The mutual benefit of such knowledge sharing led to the co-evolution of sets of adaptations, such as language, elaborated communicative emotional displays, and pedagogy that coordinate specialized processes of inferential reconstruction with the specialized production of behaviors designed to facilitate such reconstruction (e.g., Ekman, 1984; Freyd, 1983; Fridlund, in press; Pinker & Bloom, this volume; Premack, in prep.; Sperber & Wilson, 1986).

Because reconstructive inferences are often erroneous and what others "know" is often of dubious quality or irrelevant, such inferential processes could not have evolved without adaptations that assessed to some degree the value of such reconstructed knowledge and how it fits in with knowledge derived from other sources. If a representation is easy to successfully reconstruct and is evaluated positively, then it will tend to spread through inter-individual chains of inference, becoming widely shared. If it is difficult to reconstruct or evaluated as not valuable, it will have only a restricted distribution or will disappear (Sperber, 1985, 1990; Sperber & Wilson, 1986). This evaluation process gives sequentially reconstructed culture its well-known, if partial, parallels to natural selection acting on genes; that is, the selective retention and accumulation of favored variants over time (e.g., Barkow, 1989; Boyd & Richerson, 1985; Campbell, 1965, 1975; Cavalli-Sforza & Feldman, 1981; Dawkins, 1976; Durham, 1991; Lumsden & Wilson, 1981). Moreover, these psychological mechanisms endow sequentially reconstructed culture with its epidemiological character, as a dynamically changing distribution of elements among individuals living in populations over time. As Sperber says, "Cultural phenomena are ecological patterns of psychological phenomena. They do not pertain to an autonomous level of reality, as antireductionists would have it, nor do they merely belong to psychology as reductionists would have it" (1985, p. 76).

The more widely shared an element is, the more people are inclined to call it "cultural," but there is no natural dividing point along a continuum of something shared between two individuals to something shared through inferential reconstruction by the entire human species (Sperber, 1985, 1990). The Standard Model practice of framing "cultures" as sets of representations homogeneously shared by nearly all members of discrete and bounded "groups" does not capture the richness of the ecological distribution of these psychological elements, which cross-cut each other in a bewildering variety of fractal patterns. Language boundaries do not correspond to subsistence practice boundaries, which do not correspond to political boundaries or to the distribution of rituals (for discussion, see Campbell & LeVine, 1972). Within groups, representations occur with all kinds of different frequencies, from beliefs passed across generations by unique dyads, such as shamanistic knowledge or mother-daughter advice, to beliefs shared by most or all members of the group.

The belief that sequentially reconstructed representations exist primarily in bounded cells called "cultures" derives primarily from the distribution of language boundaries, which do happen to be distributed more or less in this fashion. As Pinker and Bloom (this volume) point out, communication protocols can be arbitrary, but must be shared between sender and receiver to be functional. The benefit of learning an arbitrary linguistic element is proportional to how widely it is distributed among a set of interacting individuals. Therefore, well-designed language acquisition mechanisms distributed among a local set of individuals will tend to converge on a relatively homogeneous set of elements: It is useful for all local individuals to know the same local language. Although there are other reasons why reconstructed elements may show sharp coordinated boundaries (e.g., ethnocentrism, common inheritance, sharp habitat boundaries, geographical barriers, and so on), most classes of representations or regulatory elements dynamically distribute themselves according to very different patterns, and it is probably more accurate to think of humanity as a single interacting population tied together by sequences of reconstructive inference than as a collection of discrete groups with separate bounded "cultures."

Finally, the reconstruction of regulatory elements and representations in a psychological architecture should not be thought of as a homogeneous process. Given that our minds have a large set of domain-specific mechanisms, it seems likely that different mechanisms would be selected to exploit social observations in different ways and have quite distinct procedures for acquiring, interpreting, and using information derived from the social world. Certainly, the language acquisition device appears to have its own special properties (e.g., Pinker, 1989), and many other domains appear to follow their own special rules (Carey & Gelman, 1991). It seems unlikely in the extreme that the different modules underlying mate preferences (Symons, 1979; Buss, in prep.), food preferences (e.g., Galef, 1990), display rules for emotional expression (Ekman, 1982), fears (Cook et al., 1986) and so on, process social observations according to a single unitary process. Moreover, to the extent that there may exist a large, potentially interacting store of representations in the mind (see, e.g., Fodor 1983), nothing in the psychological architecture necessarily segregates off representations derived through "epidemiological culture" from representations and regulatory elements derived from other sources.

This brief sketch suggests a few of the features future theories of culture may incorporate, once the Standard Model concept of learning is discarded. These are organized by two themes. First, what is presently attributed to "culture" will come to be pluralistically explained as metaculture, evoked culture, epidemiological culture, and individual mental contents that are internally generated and not derived through inferential reconstruction (see table below). Second, with the fall of content-independent learning, the socially constructed wall that separates psychology and anthropology (as well as other fields) will disappear. The heterogeneous mechanisms comprising our evolved psychological architecture participate inextricably in all cultural and social phenomena and, because they are content-specialized, they impart some contentful patterning to them. Indeed, models of psychological mechanisms, such as social exchange, maternal attachment, sexual attraction, sexual jealousy, the categorization of living kinds, and so on, are the building blocks out of which future theories of culture will, in part, be built (Sperber, 1990; Tooby & Cosmides, 1989a). By no means do

Table 1.1 Decomposing the Traditional Concept of Culture

Metaculture	Evoked culture	Epidemiological culture
Mechanisms functionally organized to use cross-cultural regularities in the social and nonsocial environment give rise to panhuman mental contents and organization.	Alternative, functionally organized, domain-specific mechanisms are triggered by local circumstances; leads to within-group similarities and between-group differences.	Observer's inferential mechanisms construct representations similar to those present in others; domain-specific mechanisms influence which representations spread through a population easily and which do not.

we deny or minimize the existence of emergent phenomena, such as institutions, or the fact that population-level processes alter the epidemiological distribution of cultural contents over time. The point is simply that cultural and social phenomena can never be fully divorced from the structure of the human psychological architecture or understood without reference to its design.

The Twilight of Learning as a Social Science Explanation

Advocates of the Standard Social Science Model have believed for nearly a century that they have a solid explanation for how the social world inserts organization into the psychology of the developing individual. They maintain that structure enters from the social (and physical) world by the process of "learning"—individuals "learn" their language, they "learn" their culture, they "learn" to walk, and so on. All problems—whether they are long-enduring adaptive problems or evolutionarily unprecedented problems—are solved by "learning." In the intellectual communities dominated by the SSSM, learning has been thought to be a powerful explanation for how certain things come about, an explanation that is taken to refer to a well-understood and well-specified general process that someone (i.e., the psychological community) has documented. For this reason, "learning," and such common companion concepts as "culture," "rationality," and "intelligence," is frequently invoked as an alternative explanation to so-called "biological" explanations (e.g., sexual jealousy did not evolve, it is learned from culture; one doesn't need to explain how humans engage in social exchange: They simply used their "reason" or "intelligence").

Of course, as most cognitive scientists know (and all should), "learning"—like "culture," "rationality," and "intelligence"—is not an explanation for anything, but is rather a phenomenon that itself requires explanation (Cosmides & Tooby, 1987; Tooby & Cosmides, 1990b). In fact, the concept of "learning" has, for the social sciences, served the same function that the concept of "protoplasm" did for so long in biology. For decades, biologists could see that living things were very different from nonliving things, in that a host of very useful things happened inside of living things that did not occur inside of the nonliving (growth, the manufacture of complex chemicals, the assembly of useful structures, tissue differentiation, energy production, and so on). They had no idea what causal sequences brought these useful results about. They reified this unknown functionality, imagining it to be a real substance, and called it "protoplasm," believing it to be the stuff that life was made of. It was a name given to a mystery, which was then used as an explanation for the functional results that remained in genuine need of explanation. Of course, the concept of protoplasm eventually disappeared when molecular biologists began to determine the actual causal sequences by which the functional business of life was transacted. "Protoplasm" turned out to be a heterogeneous collection of incredibly intricate functionally organized structures and processes—a set of evolved adaptations, in the form of microscopic molecular machinery such as mitochondria, chloroplasts, the Krebs cycle, DNA transcription, RNA translation, and so on.

Similarly, human minds do a host of singularly useful things, by which they coordinate themselves with things in the world: They develop skill in the local community's language; upon exposure to events they change behavior in impressively functional ways; they reconstruct in themselves knowledge derived from others; they adopt the practices of others around them; and so on. Psychologists did not know what causal sequences brought these useful results about. They reified this unknown functionality, imagining it to be a unitary process, and called it "learning." "Learning" is a name given to the unknown agent imagined to cause a large and heterogeneous set of functional outcomes. This name was (and is) then used as an explanation for results that remained in genuine need of explanation. We expect that the concept of learning will eventually disappear as cognitive psychologists and other researchers make progress in determining the actual causal sequences by which the functional business of the mind is transacted. Under closer inspection, "learning" is turning out to be a diverse set of processes caused by a series of incredibly intricate, functionally organized cognitive adaptations, implemented in neurobiological machinery (see, e.g., Carey & Gelman, 1991; Gallistel, 1990; Pinker 1989, 1991; Real, 1991). With slight qualifications about the exact contexts of usage, similar things could be said for "culture," "intelligence," and "rationality." The replacement of the concept of protoplasm with a real understanding of the vast, hidden, underlying worlds of molecular causality has transformed our understanding of the world in completely unexpected ways, and we can only anticipate that the same will happen when "learning" is replaced with knowledge.

NOTES

1. Philosophers and historians of science sometimes use the phrase "unity of science" as a term of art to refer to an axiomatized reductionistic approach to science. We are not using it in this sense, but rather in its common sense meaning of mutual consistency and relevance.

2. For a very illuminating discussion of how various "tools" (from wax tablets to general-purpose computers to methods of statistical inference) have served as metaphors for the structure of the human mind, see "From tools to theories: A heuristic of discovery in cognitive psychology" by Gerd Gigerenzer (1991a).

3. Nevertheless, given the sorry history of the social sciences, in which every new research program has loosed a deluge of half-baked nostrums and public policy prescriptions on generally unconsenting victims, an important caution is in order. The human mind is the most complex phenomenon humans have encountered and research into it is in its infancy. It will be a long time before scientific knowledge of the aggregation of mechanisms that comprise the human psychological architecture is reliable enough and comprehensive enough to provide the basis for confident guidance in matters of social concern.

4. Finding invariances in cognitive architecture should, in turn, help neuroscientists in their search for the neural mechanisms that implement them. In neuroscience (as everywhere else), researchers practicing unguided empiricism rapidly become lost in a forest of complex phenomena without knowing how to group results so that the larger scale functional systems can be recognized. The evolved functional organization of cognitive programs offers an independently discoverable, intelligible and privileged system for ordering and relating neuroscientific phenomena: The brain itself evolved to solve adaptive problems, and its particular systems of organization were selected for because they physically carried out information-processing procedures that led to the adaptive regulation of behavior and physiology.

5. In fact, the actual distribution and character of genetic variation fits well with theories that explain it as mutations, selectively neutral variants (Nei, 1987), quantitative variation and, especially, as the product of parasite-driven frequency-dependent selection for biochemical individuality (see e.g., Clarke, 1979; Hamilton & Zuk, 1982; Tooby, 1982). Briefly, the more biochemically individualized people in a community are, the more difficult it is for disease micro-organisms adapted to one individual's biochemistry to contagiously infect neighboring humans. Thus, so long as this variation doesn't disrupt the higher level uniformity of functional

integration in complex adaptations, selection will favor the maintenance of individualizing low level protein variability in the tissues attacked by parasites, generating a large reservoir of a restricted kind of genetic variability (Tooby, 1982; Tooby & Cosmides, 1990a).

6. Researchers in phenomena-oriented fields, such as personality and social psychology, usually avoid formal analysis, so one is never sure what kind of computational mechanisms are hypothesized to generate performance. And, although many who do mainstream cognitive research on memory, problem-solving, and decision-making make formal models, these are devised to predict performance on artificial, evolutionarily unprecedented tasks, such as chess-playing or cryptarithmetic. Naturally, the phenomena-oriented researchers reject the latter's formal analyses as sterile and irrelevant to their interests, whereas those who do rigorous analyses of artificial tasks regard the phenomena-oriented researchers as wooly headed and unscientific. But neither community considers the possibility that the assumptions of the SSSM might be the problem.

7. See, for example, Alexander, 1979; Atran, 1990; Barkow, 1973, 1978, 1989; Berlin & Kay, 1969; Boyer, 1990; Bowlby, 1969; Boyd & Richerson, 1985; D. E. Brown, 1991; Buss, 1989, 1991; Campbell, 1965, 1975; Cavalli-Sforza & Feldman, 1981; Chagnon, 1988, Chagnon & Irons, 1979; Cheney & Seyfarth, 1990; Chomsky, 1959, 1975, 1980; Cloak, 1975; Clutton-Brock & Harvey, 1979; Crawford & Anderson, 1989; Crawford, Smith, & Krebs, 1987; Daly & Wilson, 1981, 1984a, 1987a, 1988; Dawkins, 1976, 1982, 1986; Dennett, 1987; Dickemann, 1981; Durham, 1991; Eibl-Eibesfeldt, 1975; Ekman, 1982; Fodor, 1983; Fox, 1971; Freeman, 1983; Freyd, 1987; Fridlund, in press; Galef, 1990; Gallistel, 1990; Garcia, 1990; Gazzaniga, 1985; Gelman, 1990a; Ghiselin, 1973; Glantz & Pearce, 1989; Hamilton, 1964; Hinde, 1987; Hrdy, 1977; Irons, 1979; Jackendoff 1992; Kaplan & Hill, 1985; Keil, 1989; Konner, 1982; Krebs & Davies, 1984; Laughlin & d'Aquili, 1974; Lee & DeVore, 1968, 1976; Leslie, 1987, 1988; Lockard, 1971; Lorenz, 1965; Lumsden & Wilson, 1981; Marr, 1982; Marshall, 1981; Maynard Smith, 1982; Nesse, 1991; Pinker, 1989; Real, 1991; Rozin, 1976; Rozin & Schull, 1988; Seligman & Hager, 1972; Shepard, 1981, 1984, 1987a; Shepher, 1983; Sherry & Schacter, 1987; Spelke, 1990; Sperber, 1974, 1982, 1985, 1986, 1990; Sperber & Wilson, 1986; Staddon, 1988; Symons, 1979, 1987, 1989; N. W. Thornhill, 1991; R. Thornhill, 1991; Tiger, 1969; Tinbergen, 1951; Trivers, 1971, 1972; Van den Berghe, 1981; de Waal, 1982; Williams, 1966, 1985; Wilson, 1971, 1975, 1978; Wilson & Daly, 1987; Wolf & Huang, 1980; Wrangham, 1987.

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2

On the Use and Misuse of Darwinism in the Study of Human Behavior

DONALD SYMONS

> A biological explanation should invoke no factors other than the laws of physical science, natural selection, and the contingencies of history.
>
> GEORGE C. WILLIAMS

Darwin's theory of evolution by natural selection answered one of the great existential questions: "Why are people?" (Dawkins, 1976). But once we know why people are, a second question immediately suggests itself: "What of it?" (Medawar, 1982). Had such tough-minded thinkers of the seventeenth and eighteenth centuries as Thomas Hobbes and Samuel Johnson been apprised of Darwin's discovery, says Medawar, they might well "have demanded to know what great and illuminating new truth about mankind followed from our realisation of his having evolved" (p. 191). This essay is a meditation on the question, "What of it?"

One of the major aims of this essay is to critically analyze the following hypothesis, which many scholars believe to be entailed by the proposition that human beings are the products of natural selection: Human behavior per se can be expected to be adaptive (i.e., reproduction-maximizing), and hence a science of human behavior can be based on analyses of the reproductive consequences of human action. My critique of this hypothesis perhaps can be introduced most easily by way of an example.

Because I wrote a book about the evolution of human sexuality (Symons, 1979), I am sometimes invited to lecture on this topic. During such lectures, I present various hypotheses about the psychological mechanisms that underpin human sexual behavior and about the selective forces that shaped these mechanisms. For example, I claim that, other things being equal, men tend to be more strongly sexually attracted to women with whom they have never had sexual relations than they are to women with whom they regularly have sexual relations. This phenomenon results, I argue, not from a generalized tendency to become bored by familiarity, but from the operation of a specialized psychological mechanism. Now, there is nothing in the laws of physical science that can account for the existence of this mechanism; nor does it somehow follow as an inevitable consequence of biological law or sexual reproduction; nor does such a mechanism exist universally in male animals (indeed, many scientists, including some evolutionists, implicitly deny its existence in human males). This mechanism, I argue, was produced by natural selection during the course of human evolutionary history because opportunities sometimes existed for males to sire offspring at little "cost" (a trivial amount of sperm, a few moments of their time) by copulating with new females. Also, opportunities often existed for males of high status or excep-